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Technical Report TR 77–03

THE ENVIRONMENT OF SOUTH KOREA AND ADJACENT SEA AREAS

by

LCDR M. J. R. NESTOR, RN

SEPTEMBER 1977

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document, the product of extensive literature research, attempts to provide a single, comprehensive reference publication for operational meteorologists and decision makers in the Korean area who must work under the conditions and within the constraints imposed by local/regional, land/sea environmental factors. This publication presents extensive climatological

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20. Abstract (continued)

information, descriptions of significant meteorological phenomena, discussions of seasonal progressions and relevant forecast guidance, environmental information pertinent to selected South Korean ports, descriptions of Korean and East Asian topography and geography, and reference data in appendix format addressing regional weather types, times of sunrise/sunset and depths of thermoclines.

FOREWORD

This publication was requested by Commander, SEVENTH Fleet following a review of environmental publications available to SEVENTH Fleet and the determination that there were no current documents addressing the problem of forecasting meteorological conditions in Korea. The Naval Environmental Prediction Research Facility was asked to examine existing publications on the subject, together with other relevant studies, and to develop a single "handbook" for use by the operational forecaster in the Korean area.

During this publication's preparation, discussions with many personnel familiar with the Korean forecasting problem and a comprehensive draft publication review by members of the COMSEVENTHFLT Staff assisted greatly in determining its format and scope. However, final responsibility and, I believe, considerable credit rests with its author, Lieutenant Commander Martin J. Nestor, Royal Navy, who worked tirelessly on this (and other similar projects) while serving with this command on a Personnel Exchange Program appointment.

Since the ultimate value of a publication such as this can only be assessed by the operational user, any evaluations derived from such use would be of interest and considerable value to this command in preparing future publications of this kind.

P. A. PETIT
Captain, U.S. Navy
Commanding Officer

PREFACE

The invasion of South Korea by the North Koreans in 1950 and the continuing instability of the truce that ended those hostilities have made the Korean Peninsula and its adjacent sea areas a region of continuing strategic importance.

This conflict, no less than any other major confrontation, was substantially influenced by environmental factors: cloud cover variations, wind strength, visibility, precipitation, tidal conditions, temperature and topography, for example. It could be asserted that these influences were even more significant in Korea than in other conflicts, because the proximity of the cold NE Asian landmass to the tropical waters of the East China Sea produces a unique and very complex climate across a peninsula of intense physical relief. The success of wide-ranging Fleet operations during the Korean Conflict was very much a function of the environment; its effects on naval operations are equally significant today.

This publication is a comprehensive environmental examination of South Korea and adjacent sea areas. It attempts to explain some of the complexities of the region's climate and topography and, where appropriate, emphasize the significance of climatic factors on Fleet operations.

Topography is of particular significance in a study of the Korean Peninsula's climate; many weather features are due solely to the trajectory of the air mass and the modifications imposed upon it by terrain and water areas. Descriptions of Korean and East Asian topography, important information for those tasked with weather forecasting in the area, are given in Sections 1 and 2.

Sections 3 and 4, which discuss climate and weather systems and provide forecast guidance, are directed mainly toward the operational meteorologist. However, Para. 3.2. which summarizes the year-round climate of the Korean Peninsula, is intended for those users not requiring the more detailed discussions of climatic parameters presented elsewhere in Section 3.

Section 5 discusses environmental factors affecting the major ports used by the U.S. Navy and summarizes the significant shipping activities around the Korean Peninsula.

Sections 6 and 7 describe the South Korean Environmental Network and provide brief summaries of significant environmental parameters relevant to Fleet operations. Charts and discussions of reference interest to operations personnel and forecasters are contained in Appendices A, B and C.

The comprehensive nature of this publication, together with the constraints inherent in developing a single, unclassified document, obviously necessitated the omission of some material. However, it is hoped that the selective use of the publication, according to the particular user's requirements, will provide environmental support for a broad cross-section of naval operations in the South Korean area.

ACKNOWLEDGMENTS

Although this publication nominally represents the work of one author, it reflects the suggestions and constructive comments of many reviewers. Special thanks are extended to CDR Neil O'Connor, USN, who, as Staff Meteorologist to Commander Seventh Fleet, provided valuable guidelines for the content and scope of the publication. Appreciation is also expressed to Mr. Young K. Chang for his translation services; to Headquarters Staff and Detachments, 1st Weather Wing, USAF, for providing selected data; and to several personnel of the Naval Environmental Prediction Research Facility for their help in producing this document: Mr. Stephen Bishop, editorial services; Mr. Mason Ridlen, graphics coordination; Mr. Stephen Myrick, photographic services; and Mrs. Winona Carlisle and Miss Susan Tilley, manuscript typing. The staff of Publishers Art Service, Monterey, California are thanked for their valuable graphics advice and subsequent production of the publication's numerous illustrations.

CONTENTS

SECTION 1

CONTENTS

1. GENERAL GEOGRAPHY

1.1 PHYSICAL DIMENSIONS

The strategic concept of the Korean Peninsula as a political "frontier" has a basis in its physical geography (Figure 1-1). In many respects it represents the transition zone between the continental landmass of northeast Asia and the island arcs rimming the Western Pacific. The Peninsula, now divided between north and south, extends to within 120 mi (190 km) of both Honshu, the main island of Japan, and the Shantung Peninsula of China. The distance between the Japanese islands of Tsushima and the South Korean island of Kuksom* is no more than 21 mi (34 km), while the nearest islands to China lie some 100 mi (160 km) off the Shantung coast.

The Korean Peninsula extends 600 mi (965 km) from latitude 44°N to 33°30'N (the same latitudes in the United States as New England to South Carolina) and has a total area, including the offshore islands, of 85,269 sq mi (220,847 sq km). This is an area roughly the size of Minnesota or Nebraska and somewhat less than Great Britain. There are 10,793 mi (17,300 km) of coastline near which lie some 3,300 offshore islands, about 300 of them inhabited.

The Peninsula is broadest at its northern border and narrowest at its center (about 135 mi/215km) where a military demarcation line divides North and South Korea.

The Republic of Korea (the official title for South Korea) has an area of 38,175 sq mi (98,477 sq km), which is about 45% of the total Peninsula and is roughly the size of Indiana or Virginia. It has a north-south extent of about 300 mi (480 km) and a maximum east-west extent of about 185 mi (295 km). (These figures do not include the southern part of the demilitarized zone (DMZ), which is not under the jurisdiction of the Republic.)

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*The spellings of place names used in this publication follow the McCune-Reischauer system adopted by the U.S. Army during World War II and now used as the prescribed standard for official agencies of the U.S. Government. The McCune-Reischauer system results in the best approximation of the Korean pronunciations of place names by foreigners unfamiliar with the language.

1.2 NATIONAL BOUNDARIES

1.2.1 The Demilitarized Zone (DMZ)

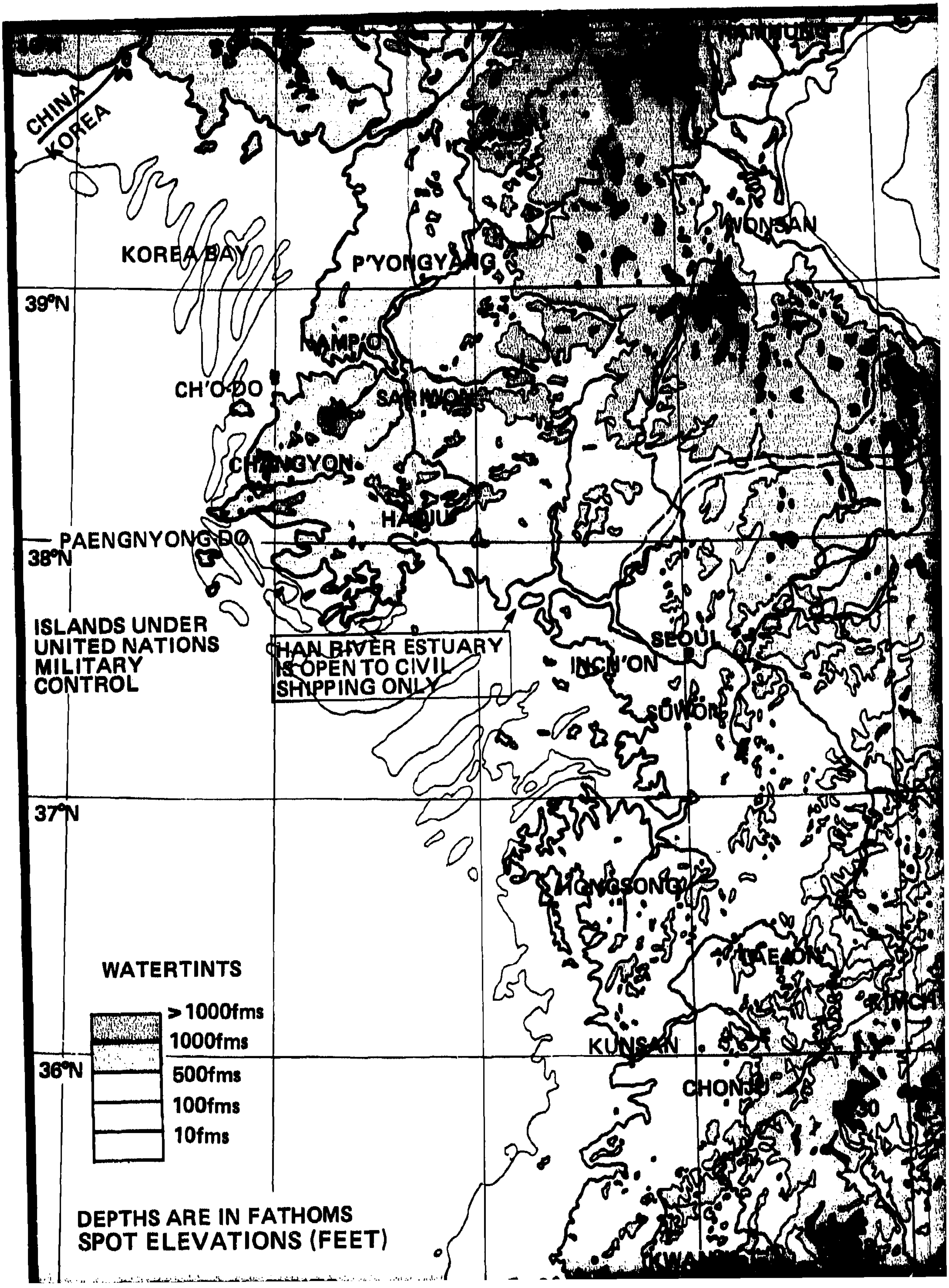
South Korea's only land boundary is that with North Korea. This division lies within a demilitarized zone which represents the front between the opposing forces at the time of the Korean Armistice in 1953. The zone extends 151 mi (240 km) across the Peninsula from the Han River Estuary in the west to just below the 39th Parallel on the east coast (Figure 1-1). The zone is about 2.5 mi (4 km) wide and has a military demarcation line down the center, one yellow marker visible to the next. About three quarters of its length is over land, through rugged brush or forest-covered hills and mountains, and the remainder is in the waters of the Han and Imjin rivers. There are no economic activities in the DMZ except for two token villages (one maintained by each side) close to Panmunjon. Both sides of the zone are heavily fortified.

1.2.2 The Sea of Japan and East Coast of South Korea

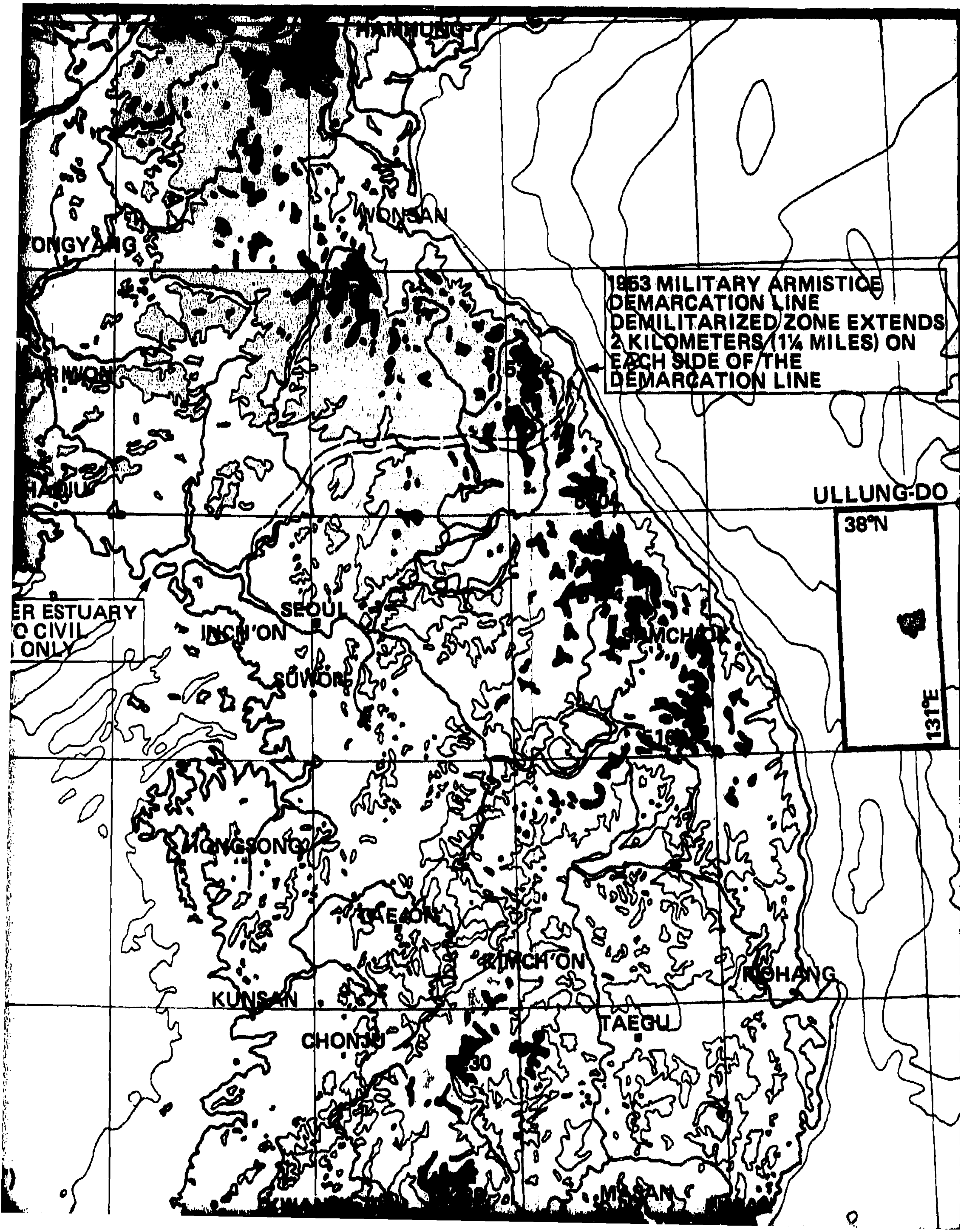
Strategically, the Sea of Japan is very important. Vladivostok, the principal Soviet military port in the Pacific region is located in the ice-free portion of this sea and the Soviet Pacific Fleet must pass through one of four possible straits to enter and return from the Pacific Ocean. Only the Tsushima Strait off South Korea allows year-round accessibility to the Sea of Japan.

The Sea of Japan has very different characteristics from those of the Yellow Sea to the west. It has an area of some 250,000 sq mi (402,250 sq km) and is very deep, with an average depth around 5000 ft (1540 m) and a maximum depth of 13,284 ft (4049 m). The distance from the Korean coast to the nearest opposite shore of the sea is approximately 800 n mi (1500 km).

Yongil Bay, the location of Pohang (36°02'N, 129°23'E), is the only sizeable bay along the otherwise relatively straight east coast (Figure 1-2). A deep water harbor has been constructed on its southern rim behind extensive breakwaters in anticipation of considerable industrial development. The bay, which extends along four miles of coastline, lies at the mouth of the Hyongsan River.



CHINA
KOREA
KOREA BAY
P'YONGYANG
WONSAN
39°N
NAMP'O
CH'O-DO
CHANGYON
HAEJU
PAENGNYONG-DO
38°N
ISLANDS UNDER
UNITED NATIONS
MILITARY
CONTROL
HAN RIVER ESTUARY
IS OPEN TO CIVIL
SHIPPING ONLY
SEOUL
INCH'ON
SUWON
37°N
HONGSONG
TAEJON
KUNSAN
36°N
CHONJU
WATERTINTS
>1000fms
1000fms
500fms
100fms
10fms
DEPTHS ARE IN FATHOMS
SPOT ELEVATIONS (FEET)


WONSAN
ONGYANG
1953 MILITARY ARMISTICE
DEMARCATION LINE
DEMILITARIZED ZONE EXTENDS
2 KILOMETERS (1¼ MILES) ON
EACH SIDE OF THE
DEMARCATION LINE
ULLUNG-DO
38°N
131°E
ER ESTUARY
O CIVIL
ONLY
SEOUL
INCH'ON
SUWON
SAMCH'OK
HONGSONG
TAEJON
KIMCH'ON
POHANG
KUNSAN
CHONJU
TAEGU
MASAN

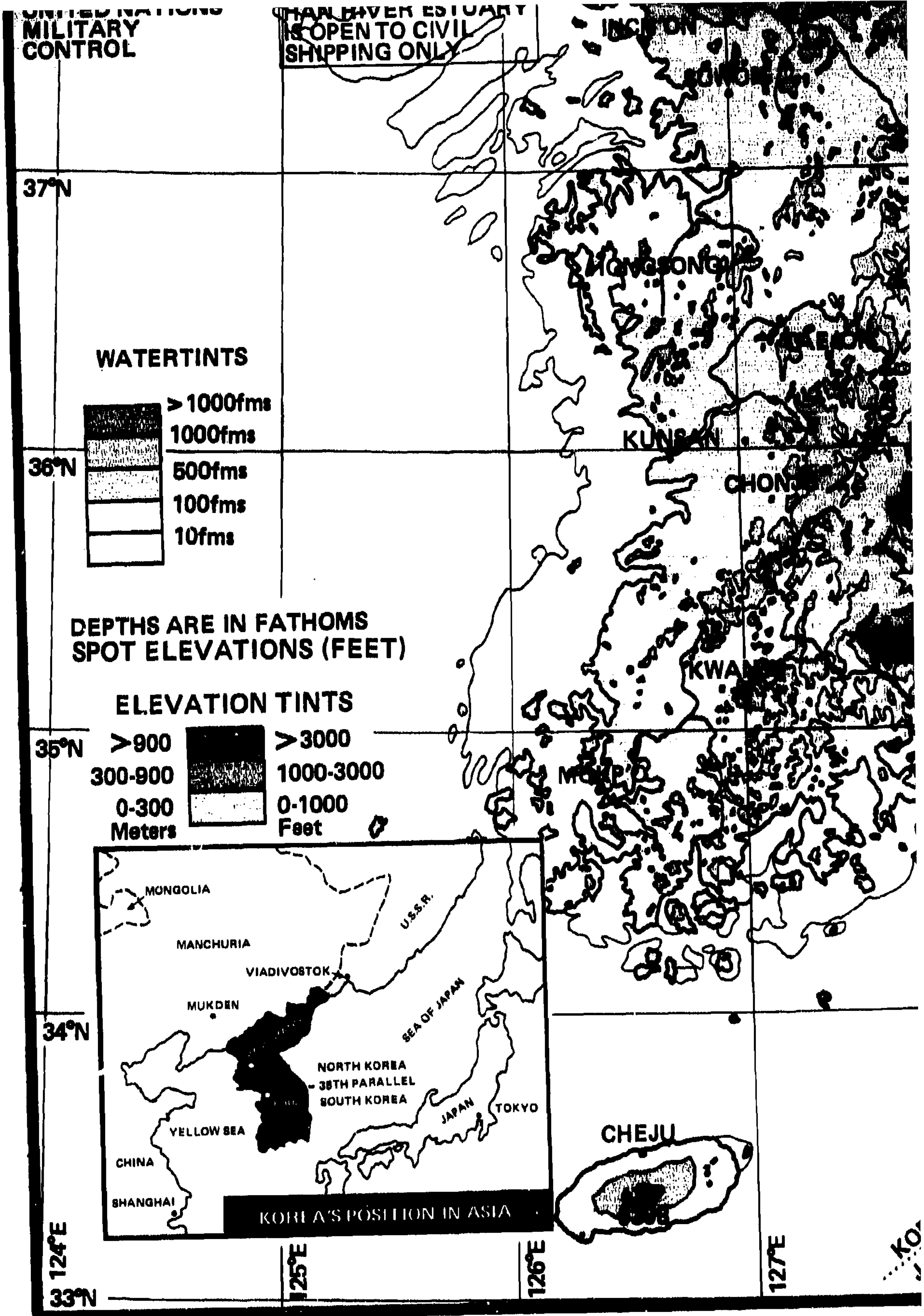


Figure 1-1. South Korea

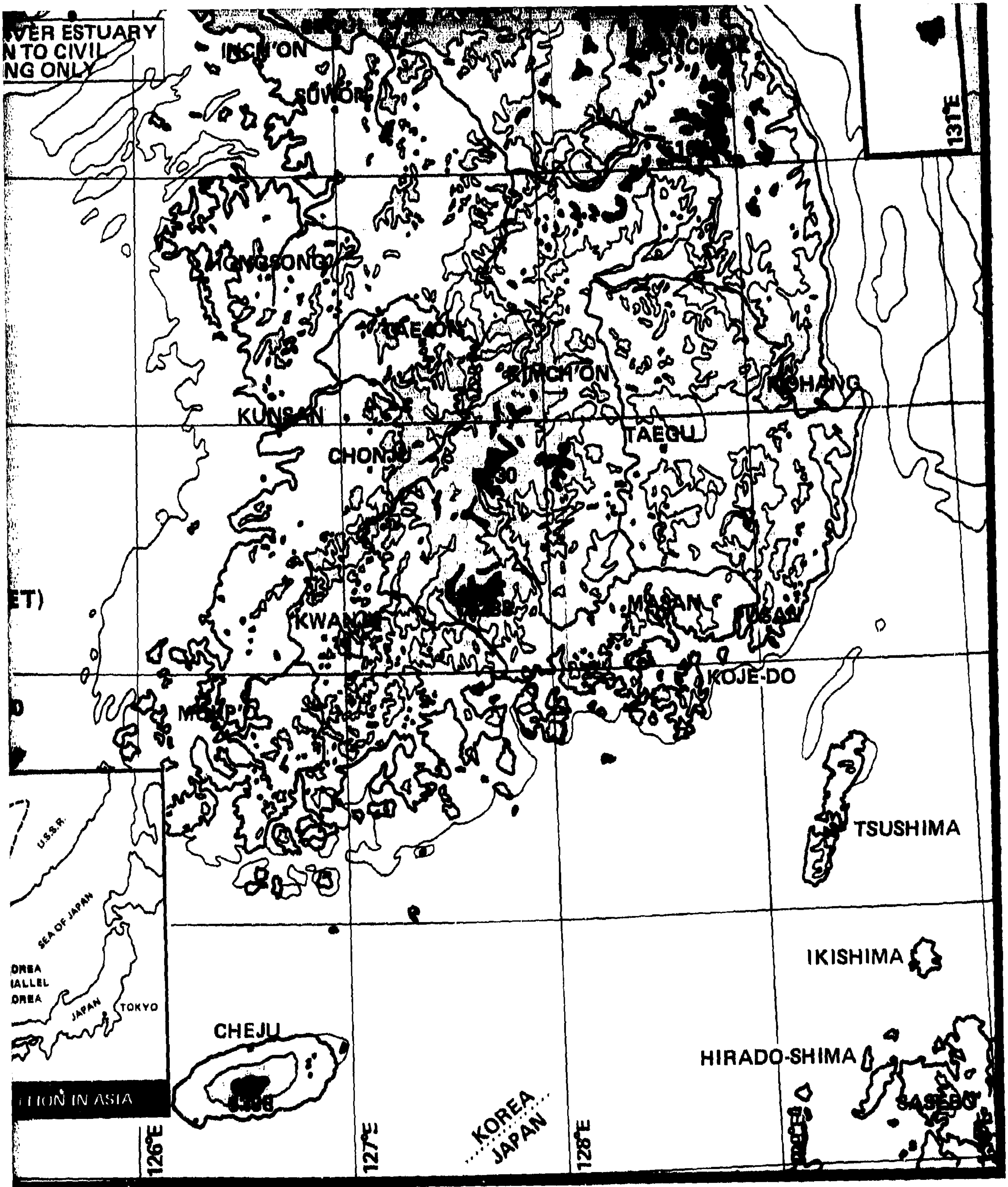
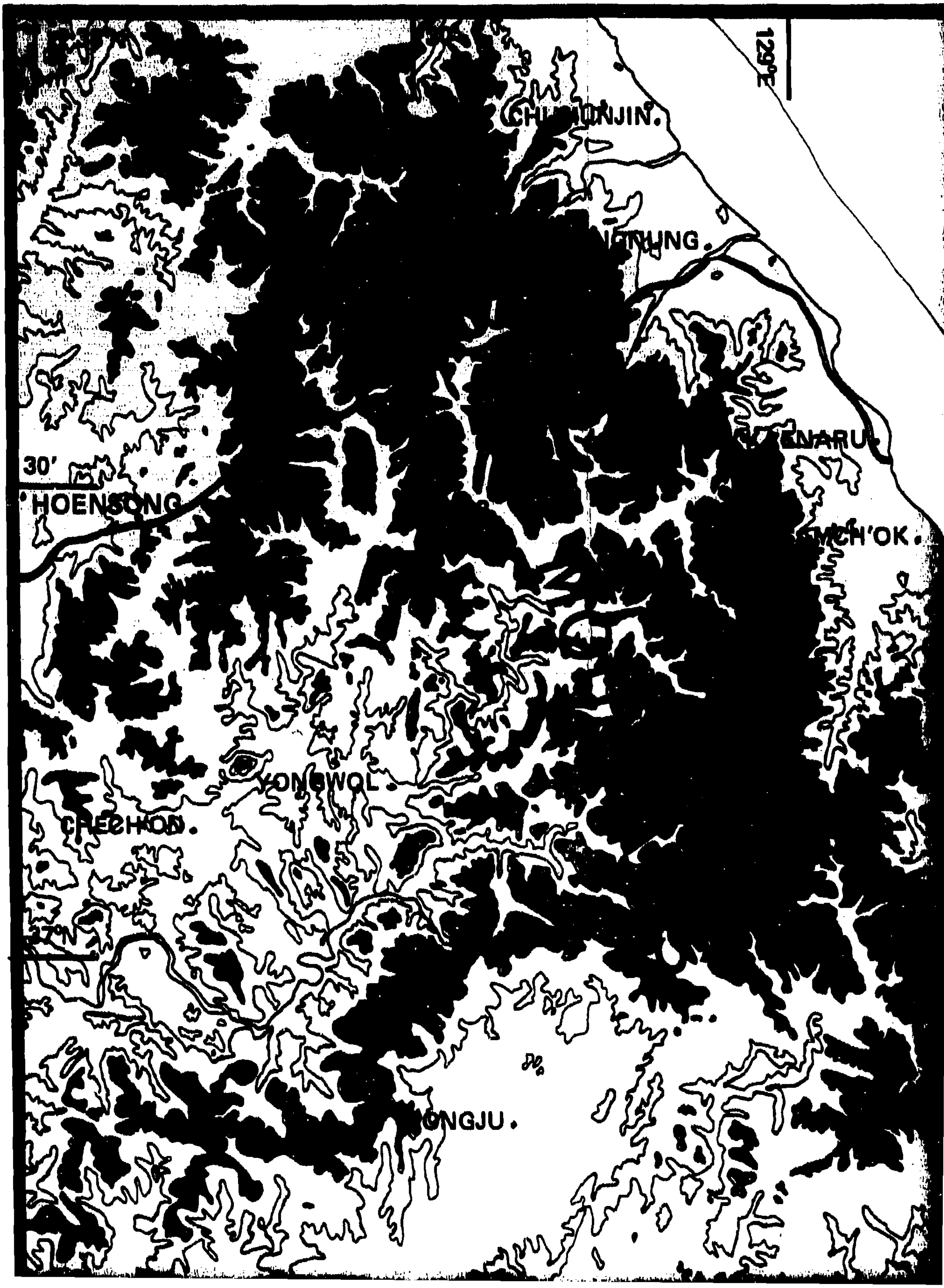
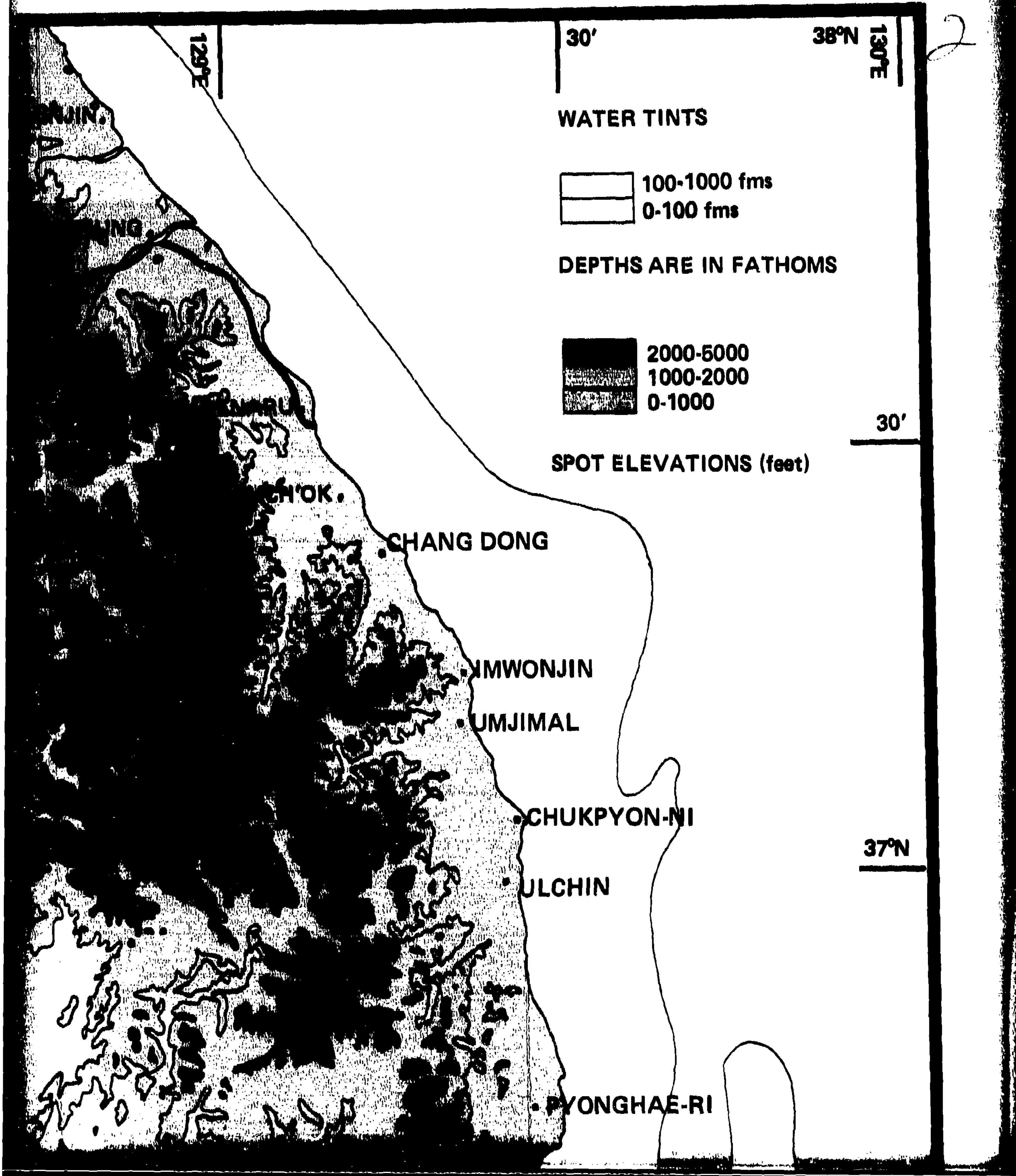
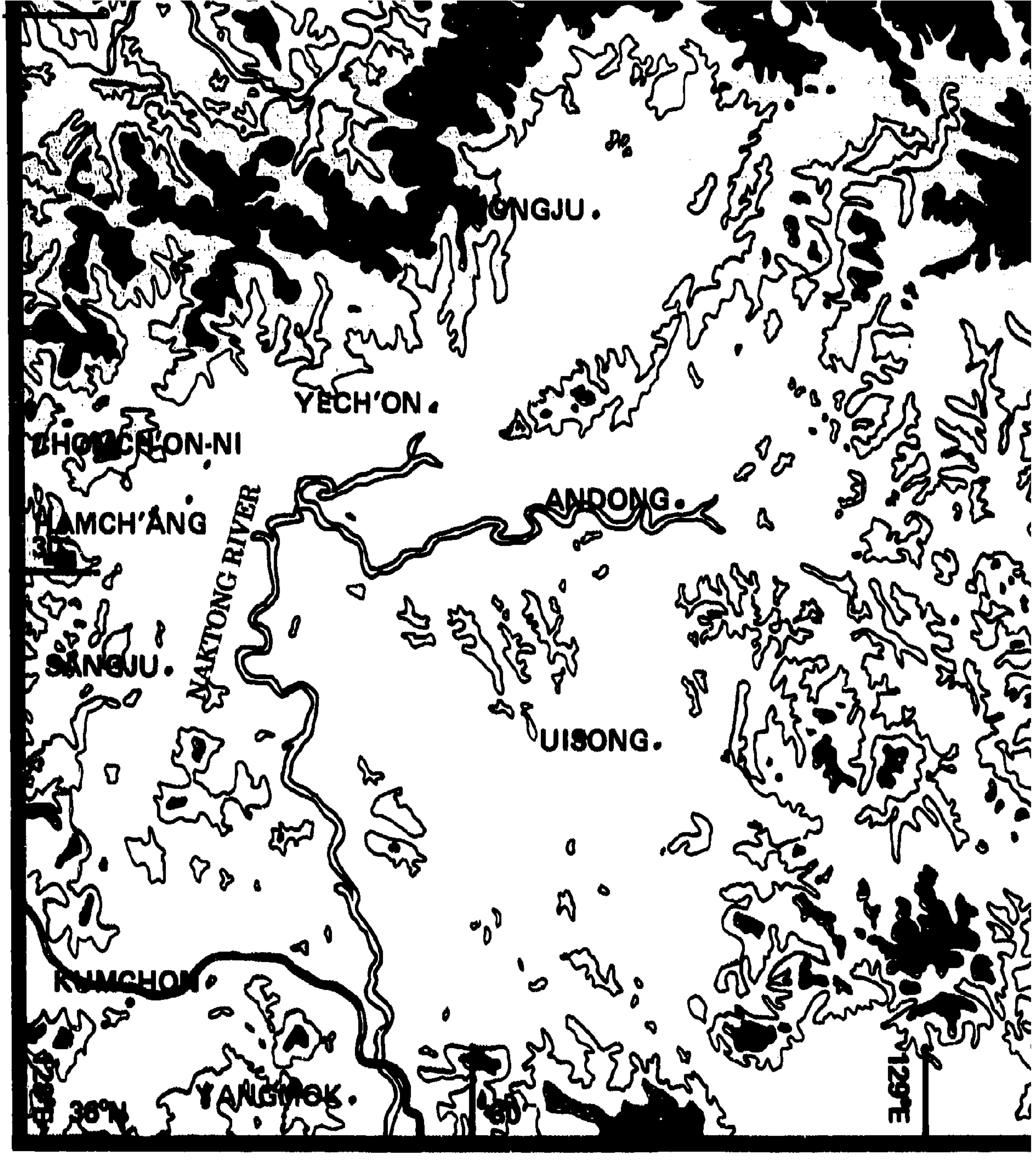


Figure 1-1. South Korea's major topographical features and position in Asia.


129°E
30'
HOENSONG
YONGWOL.


129°E
30'
38°N
130°E
WATER TINTS
100-1000 fms
0-100 fms
DEPTHS ARE IN FATHOMS
2000-5000
1000-2000
0-1000
30'
SPOT ELEVATIONS (feet)
CH'OK
CHANG DONG
IMWONJIN
UMJIMAL
CHUKPYON-NI
37°N
ULCHIN
PYONGHAE-RI



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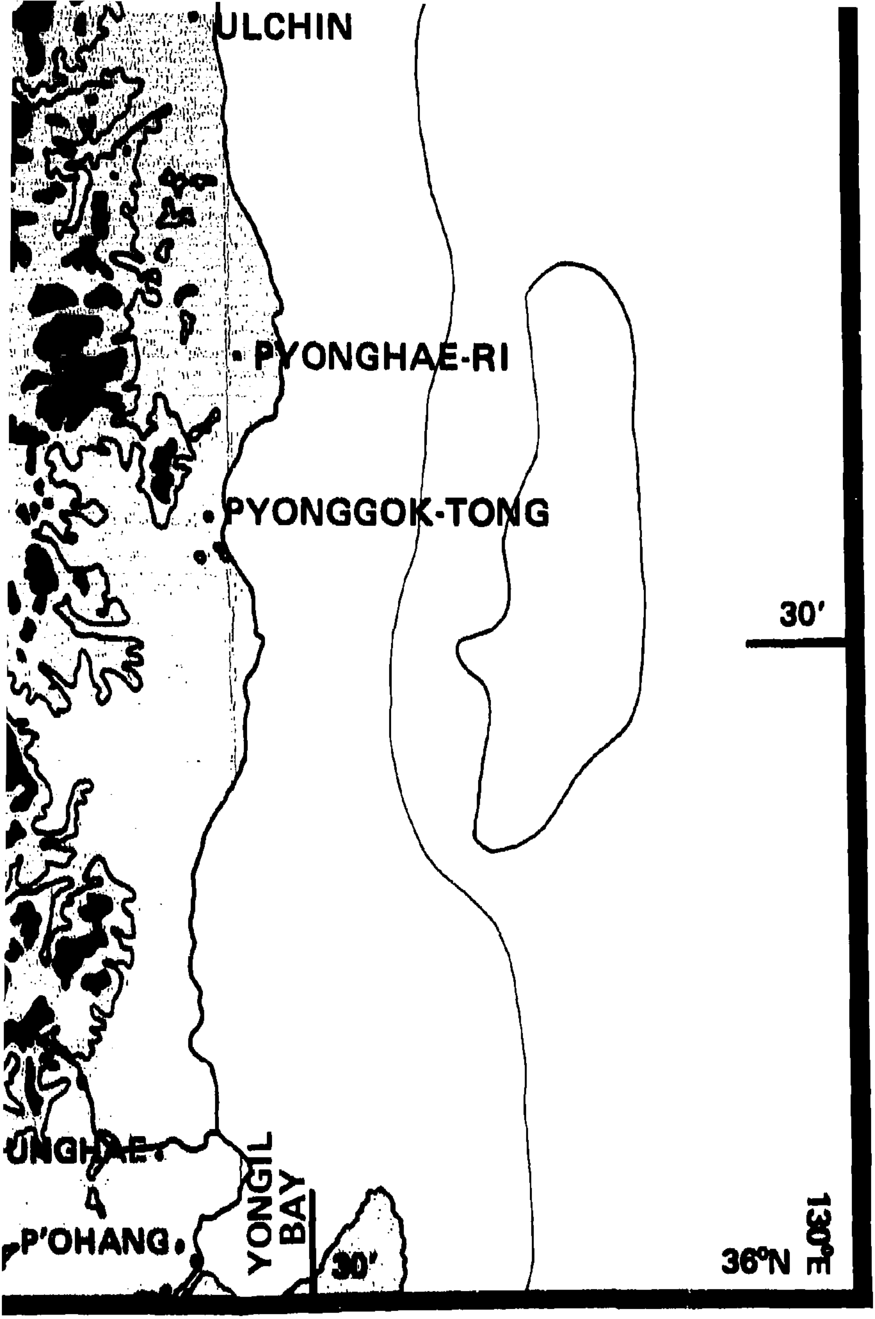


ure 1-2. Major topographical features of South Korea's eastern region.

The east coast has emerged by a process of geological uplift; the Taebaek Mountains are close to the shore and there are a series of short rivers, small alluvial coastal plains, and rocky headlands separated by pockets of lowland and sandy beach. The average distance from the Sea of Japan shoreline to the Taebaek Mountains is approximately 12 mi/20 km (Figure 1-3). The beaches are mainly sand and tend to remain firm even in the wetted areas. The bottom, close off the beaches, is usually sand mixed with mud, gravel or pebbles (ref. Figure 2-5). The short streams flowing in narrow, steep valleys have formed a succession of tiny plains separated from one another by extensions of the hills to the east. The entire coast is rather isolated and has a relatively low population density. There are a number of small fishing ports, but level land for agriculture is very much limited The tidal range of 8-15 inches on this coast is so slight as to be barely noticeable (see Para. 3.4.4).

Figure 1-3. The southern end of the Taebaek Mountains — a north-south stretch of the east coast shows the narrow coastal strip (Bartz, 1971).

Temperatures along the east coast are influenced by the influx of warm waters from the south via the Tsushima current (Para. 3.4.1). The northern limits of this warm water flow vary from season to season, being in the vicinity of the DMZ in summer and as far south as Pohang in winter. The depth of the current varies from a maximum of approximately 300 ft (91 m) to 100 ft (30 m). near the shoreline.

The mouths of the rivers are frequently blocked by sandbars, producing lagoons on the shoreward side of the dunes; the most notable example of this phenomenon occurs at Kyongpodae on the Kangwon coastline. At Sokcho (38°27'N, 28°28'E), the sandbar does not completely enclose the small bay and there remains a narrow entrance to a well-protected harbor which has become one of South Korea's largest fishing ports.

About 100 mi (160 km) off the east coast is the island of Ullung Do (37°29'N, 130°54'E), formed like Cheju Do (an island off the south coast) by the volcanic eruptions of the Peninsula's last geological upheaval. The island, a jagged volcanic peak no more than 8 mi (13 km) across, reaches a height of over 3000 ft (900 m) in Mt. Soningbong. The island's coastline is strangely carved by wave erosion (Figure 1-4), which makes approach from seaward very difficult. The population of Ullung Do depends largely on squid fishing for a livelihood. Further to the east some 125 mi (201 km) from Ulchin, (lat 37°N), off the coast of Kyongsang Pukto, lie two small uninhabited islands collectively known as Tokto. Ownership of these two small islands has been a subject of discussion between South Korea and Japan.

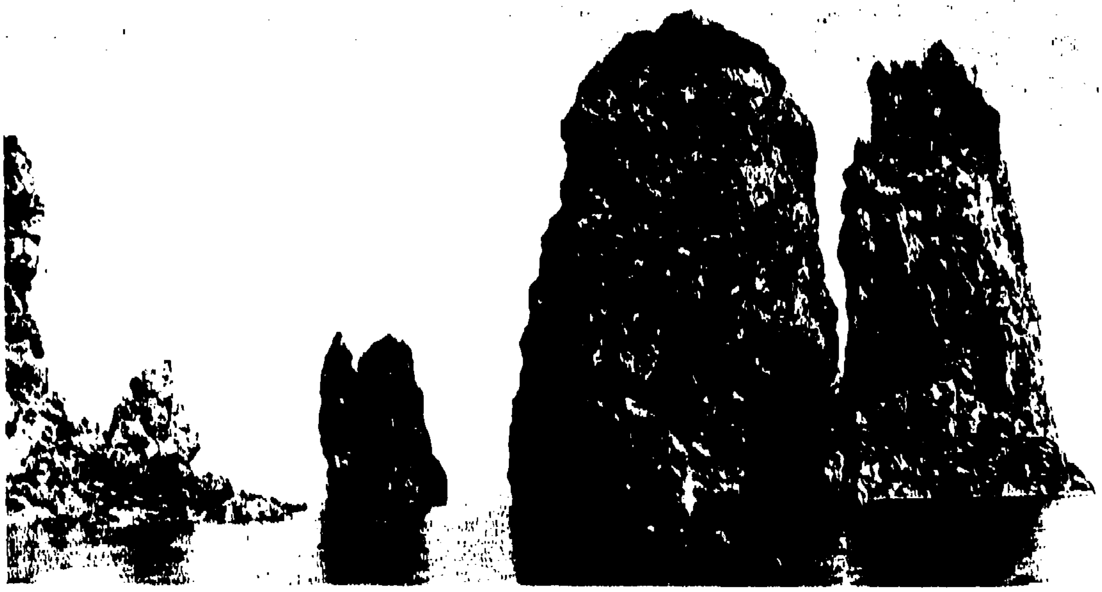


Figure 1-4. Wave-eroded volcanic rocks along the coast of Ullung-do (Bartz, 1971).

1.2.3 The Yellow Sea and West Coast of South Korea

In contrast to the east, the west coast is an area of geological submergence which has produced many peninsulas and bays and hundreds of islands (Figure 1-5). An example is the province of Chungchong Namdo (South Chungchong), which has a straight-line coast of some 90 mi (145 km) but a total coastal length of approximately 800 mi (1287 km) with 263 proximate offshore islands.

Small river plains make up most of the coastal lowland south of Seoul and extend 10-50 mi (16-80 km) inland from the Yellow Sea. The lowland is interspersed with hilly tracts extending from the interior mountains to the sea. The coast itself is extremely indented, with flooded lower courses of streams alternating with rocky headlands that in places degenerate into offshore islands. Oozing mudflats line the shores except for those places where headlands extend out into the Yellow Sea. Sea depth averages approximately 150 ft (46 m), reaching a maximum depth of about 300 ft (90 m) all the way across to the Chinese mainland. The tidal range, again in complete contrast to that of the Sea of Japan, is the second largest in the world, with a variation of 10-30 ft (3-9 m). The difference between high tide and low tide at Inchon averages 19 ft (6 m) and can reach as much as 32 ft (10 m) (see Para. 3.4.4); this tremendous tidal range is caused by the shallowness of the Yellow Sea. Tidal differences in the quantity of water being delivered from the Pacific predictably create large rises and falls in such a shallow sea basin as the Yellow Sea; moreover, the rapid ebb and flow of the tide creates powerful currents that can reach as high as 8 kt in some of the island channels.

At low tide, 1100 sq mi (1770 sq km) of mudflats extending in many places to 200 mi (320 km) offshore are exposed. Rivers are estimated to carry some 400,000 tons of silt out to sea each year and most of it goes to the Yellow Sea. Using the Defense Meteorological Satellite Program (DMSP) imagery, the Han River sediment plume entering the sea and the coastal turbidity features along the west coast of the Korean Peninsula can be clearly seen (Figure 1-6).

Many shallow arms of the sea have been diked off and the land has been reclaimed for agricultural use. The shallowness of the water leads to greater variations of sea surface temperature than those experienced in the Sea of Japan. In the shallow areas close to the coast, temperatures can rise to 80°F in the summer and fall to 35° F in winter; nowhere do they reach the freezing point. Salinity varies with season and can diminish quite markedly when the monsoon floods of summer pour into the Yellow Sea.

Natural harbors are few on the west coast because of the tidal range and the silted channels, and only Inchon has been developed as a major port area. The lower courses of the river, however, are suitable for limited navigation and many small coastal ports have been established despite the dangers and navigation difficulties posed by the rocky coast and very high tidal range.

1.2.4 The Korea Strait and South Coast of South Korea

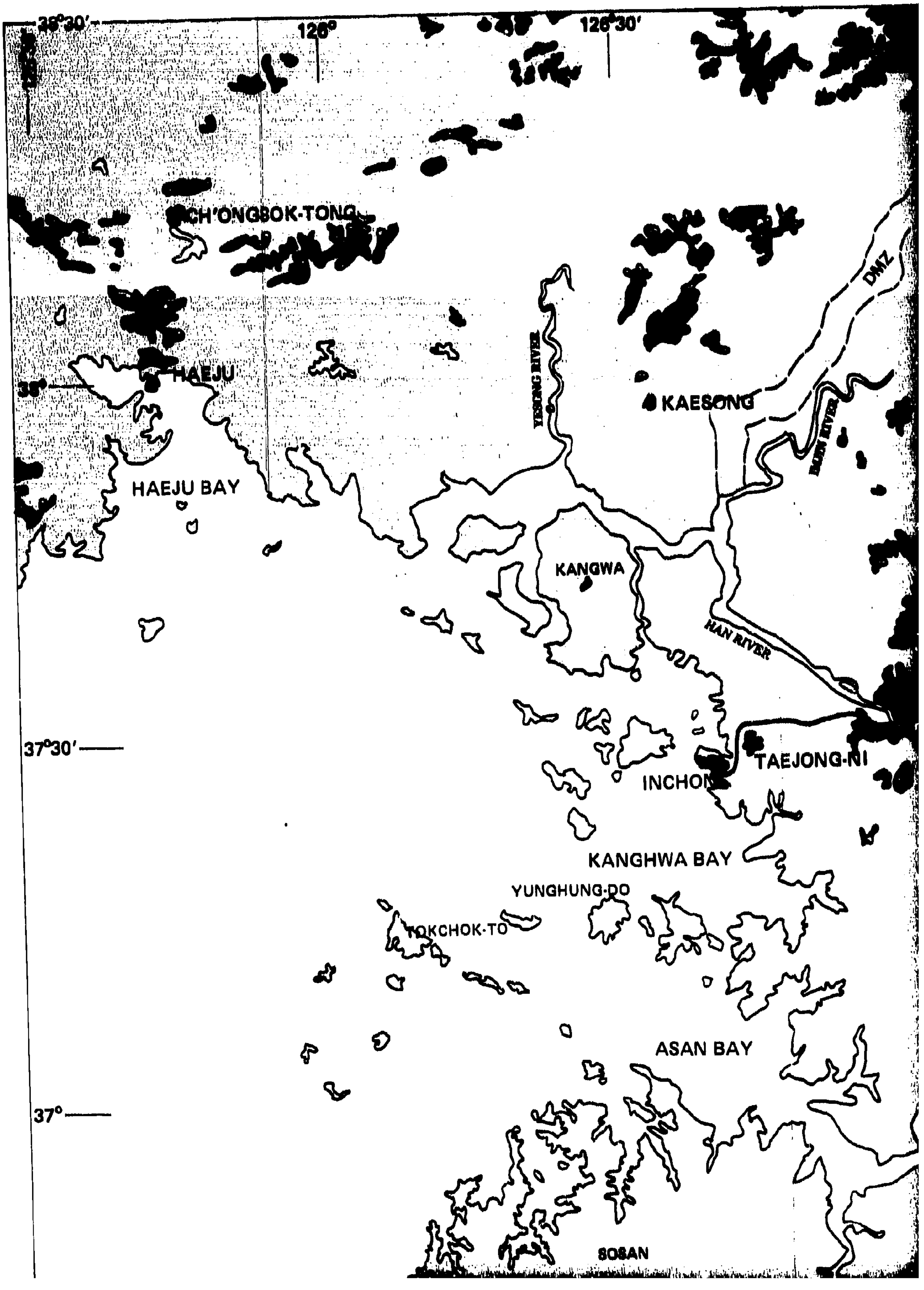
The division between the west coast bordered by the Yellow Sea and the south coast bordered by the Korea Strait (Figure 1-7) lies along a line extending southwest from Mokpo (34°45'N, 126°22'E) at the Peninsula's southwestern tip. Granitic rocks are thought to extend along this line in an undersea ridge to mainland China. Along this ridge, islands extend as much as 65 mi (104 km) to the southwest. The strait is about 150 n mi (280 km) in length and has a breadth of about 110 n mi (200 km). The depth of water varies from approximately 150 ft (45 m) to 500 ft (150 m) in the deepest part.

On this southern coast, where the various arms of the Sobaek Mountains reach the sea, a number of small structural basins are found. Offshore, the basins contain deep water and create an extremely intricate coastline of extensive, highly irregular peninsulas enclosing equally irregular bays.

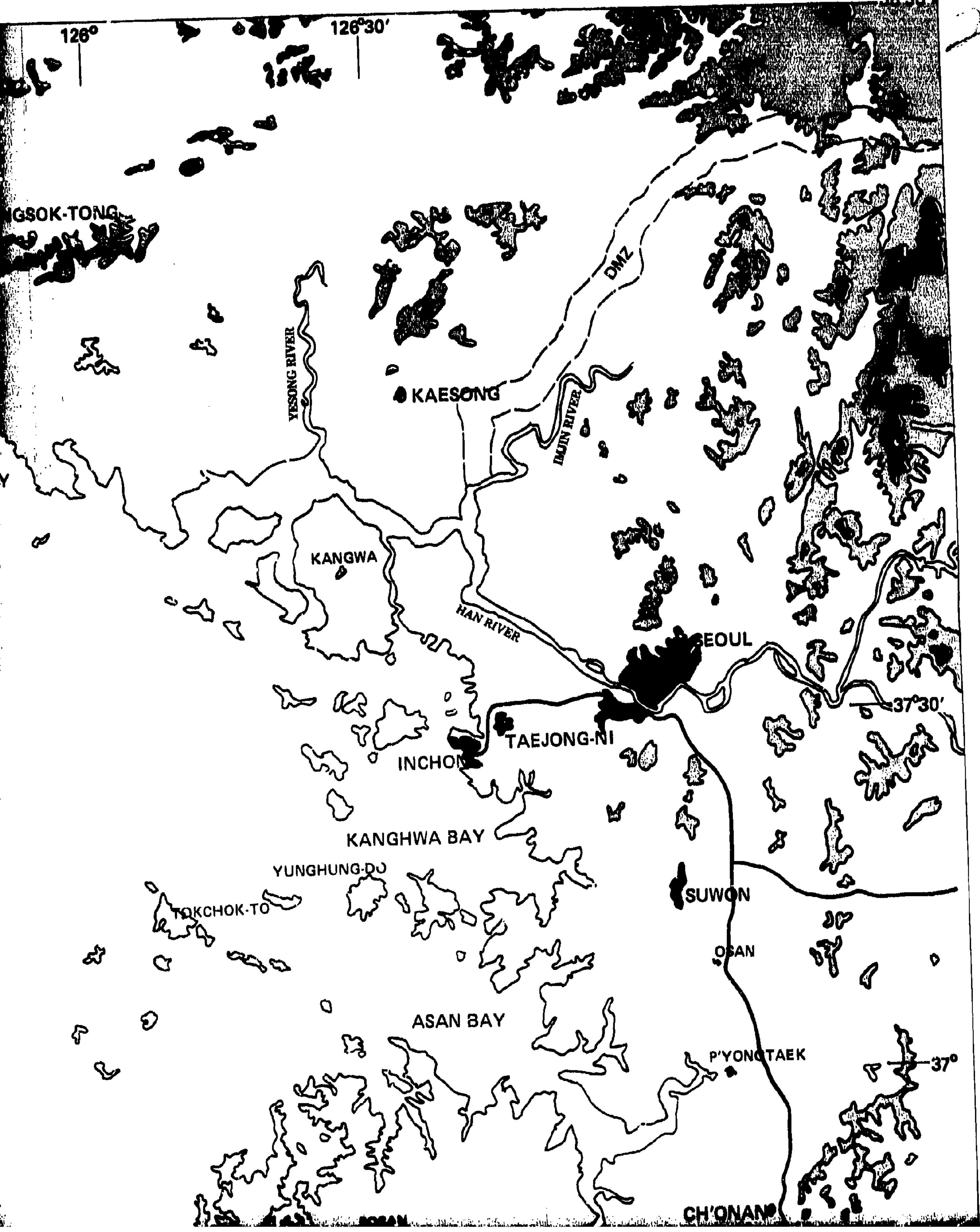
The south coast, described geologically as a submerged coastline, features a maze of more than 2000 islands, the largest of which are Koje-do, Namhae-do and Chindo (Figure 1-7). Many of the peninsulas, such as the one on which Yosu stands (34°44'N, 127°44'E), are connected to the mainland by such narrow strips of land that they are almost "islands."

The indentations on the southern coast and the more modest tidal range have permitted the development of a number of ports. The tidal range increases westward from 4 ft (1.2 m) at Pusan to 11 ft (3.3 m) at Yosu (see Para. 3.4.4). Although shallow waters extend far from shore with muddy waters extending as far as Cheju-do island (Figure 1-7), the problem of siltation is nowhere near as great as in the Yellow Sea. The direction of flow of the Tsushima Current alternates twice daily near shore along this southern coast, flowing west at ebb tide and east on the flood tide with the most rapid flow occurring in the Korea Strait between Pusan and the Tsushima Islands of Japan. These islands constitute the dividing line between the Korea Strait to the northwest and the Tsushima Strait to the southeast. Pusan at the eastward end of the Korea Strait has the best natural harbor in South Korea and is the country's principal port (see Para. 5.3).

The Naktong River is the major river along the south coast and enters the sea through a multi-channeled delta immediately west of the city of Pusan. The delta itself, subject to floods and silting, offers no opportunities for development as a port. The low flow of the Naktong has in the past allowed seawater to intrude up the channels of the delta, causing irrigation problems in the lower reaches; dam construction has been undertaken to regulate the flow of the river, which is 14 times as great in July as it is in January. Five of the six southern coastal cities are located where indentation has allowed the development of ports.



38°30'
126°
126°30'
CH'ONGBOK-TONG
HAEJU
38°
HAEJU BAY
KAESONG
DMZ
YESONG RIVER
IMJIN RIVER
KANGWA
HAN RIVER
37°30'
TAEJONG-NI
INCHON
KANGHWA BAY
YUNGHUNG-DO
TOKCHOK-TO
ASAN BAY
37°
SOSAN



38°30'
126°
126°30'
GSOK-TONG
YESONG RIVER
KAESONG
DMZ
IMJIN RIVER
KANGWA
HAN RIVER
SEOUL
37°30'
TAEJONG-NI
INCHON
KANGHWA BAY
YUNGHUNG-DO
TOKCHOK-TO
SUWON
OSAN
ASAN BAY
P'YONGTAEK
37°
CH'ONAN

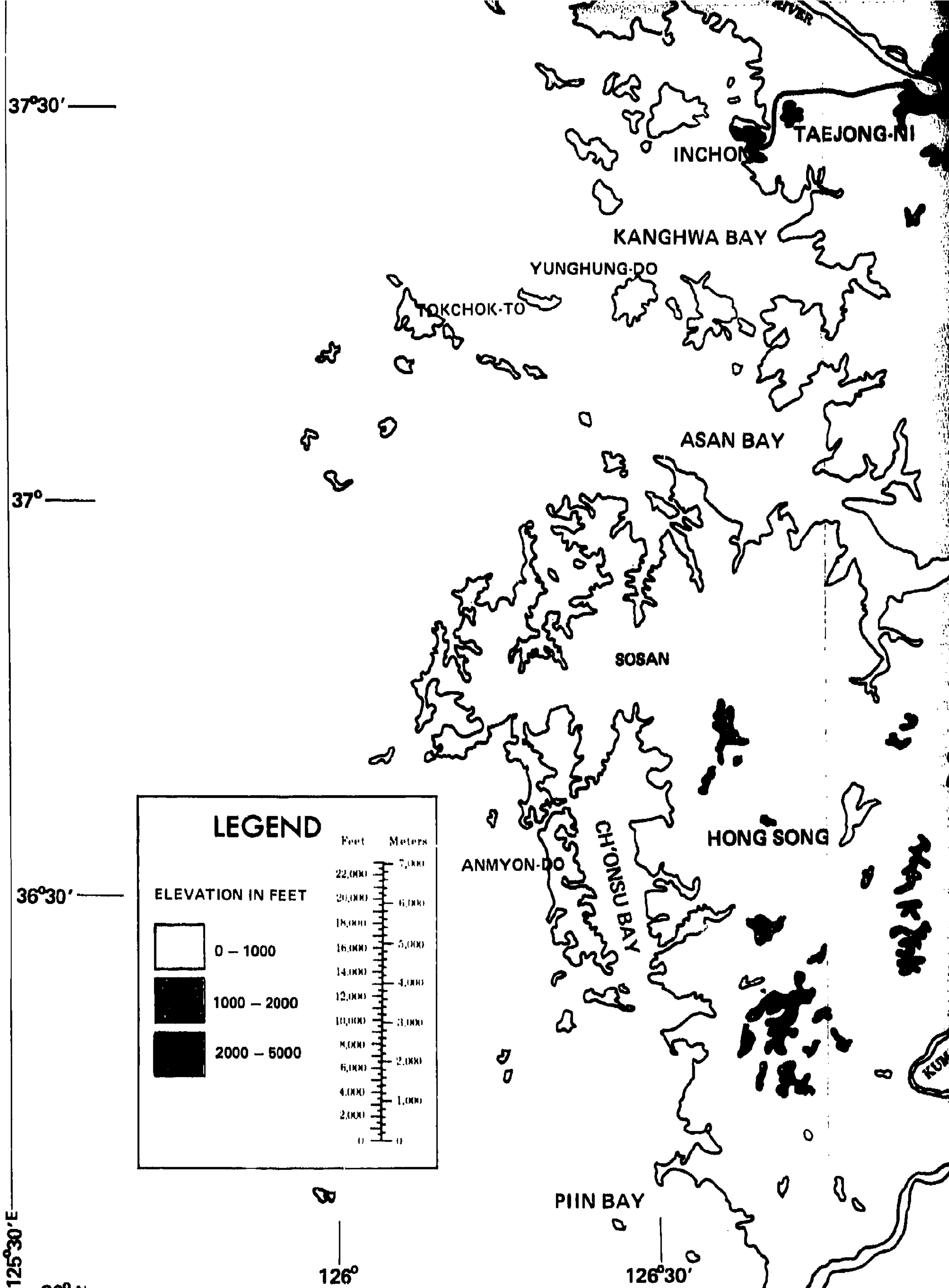


Figure 1-5. Major topographical features

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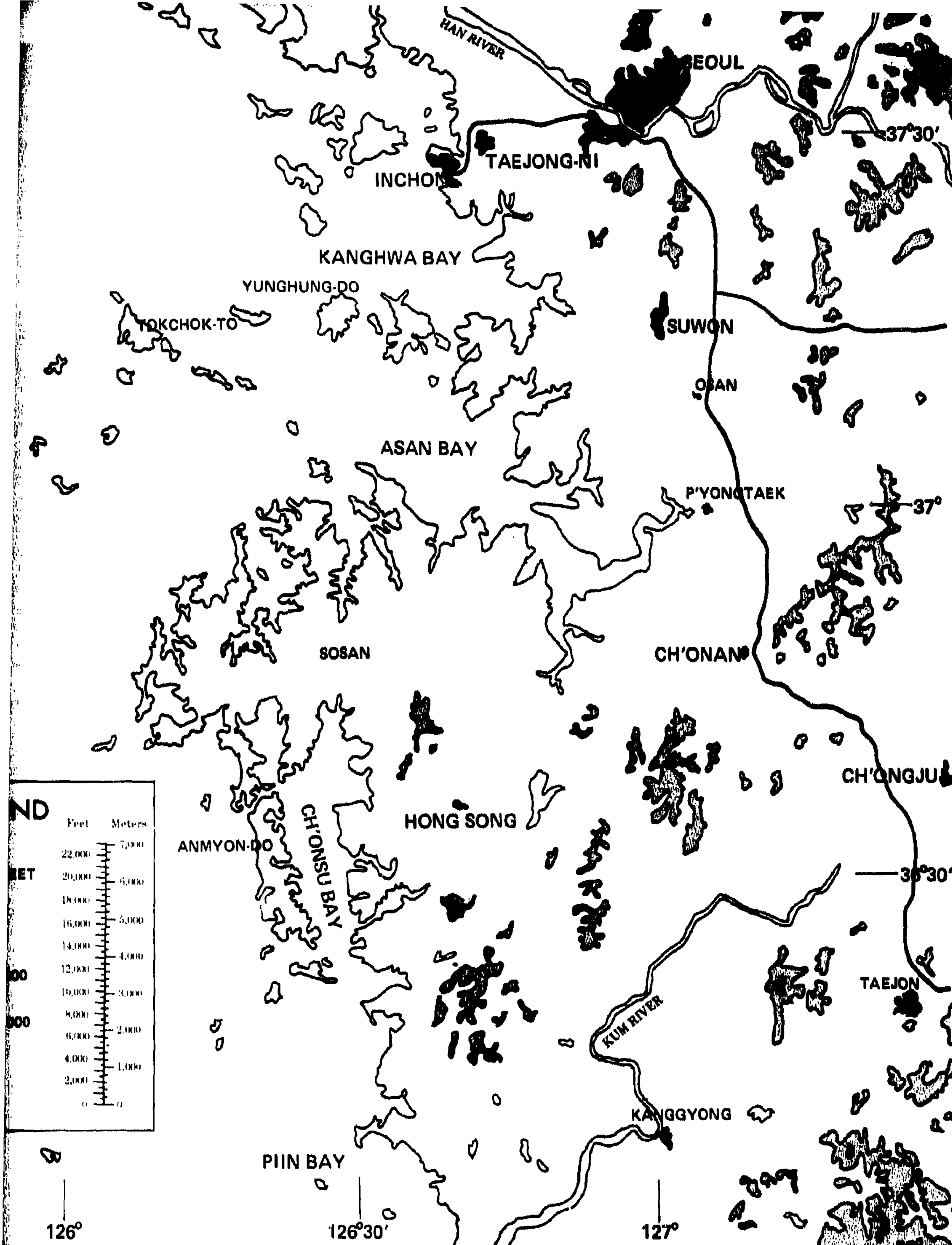


Figure 1-5. Major topographical features of South Korea's western region.

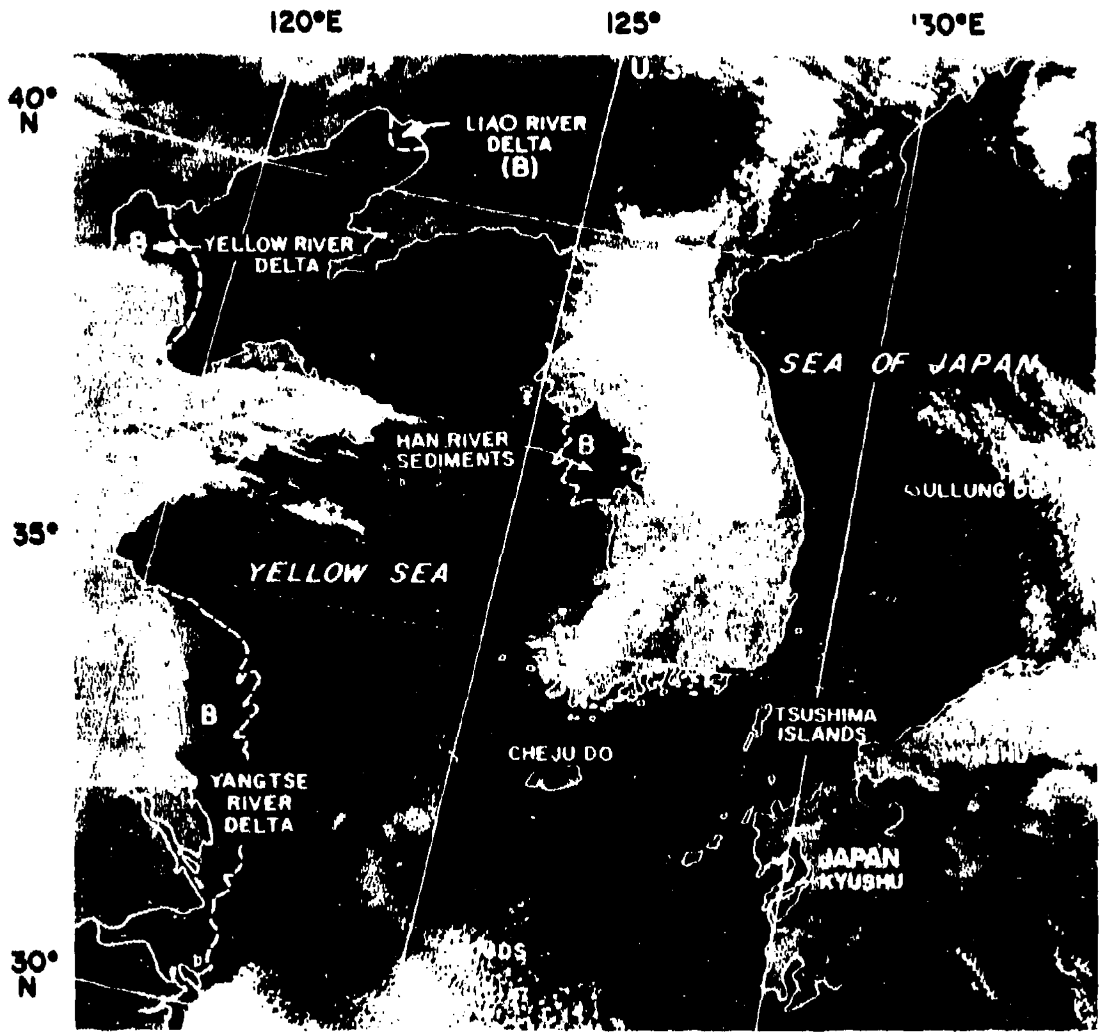
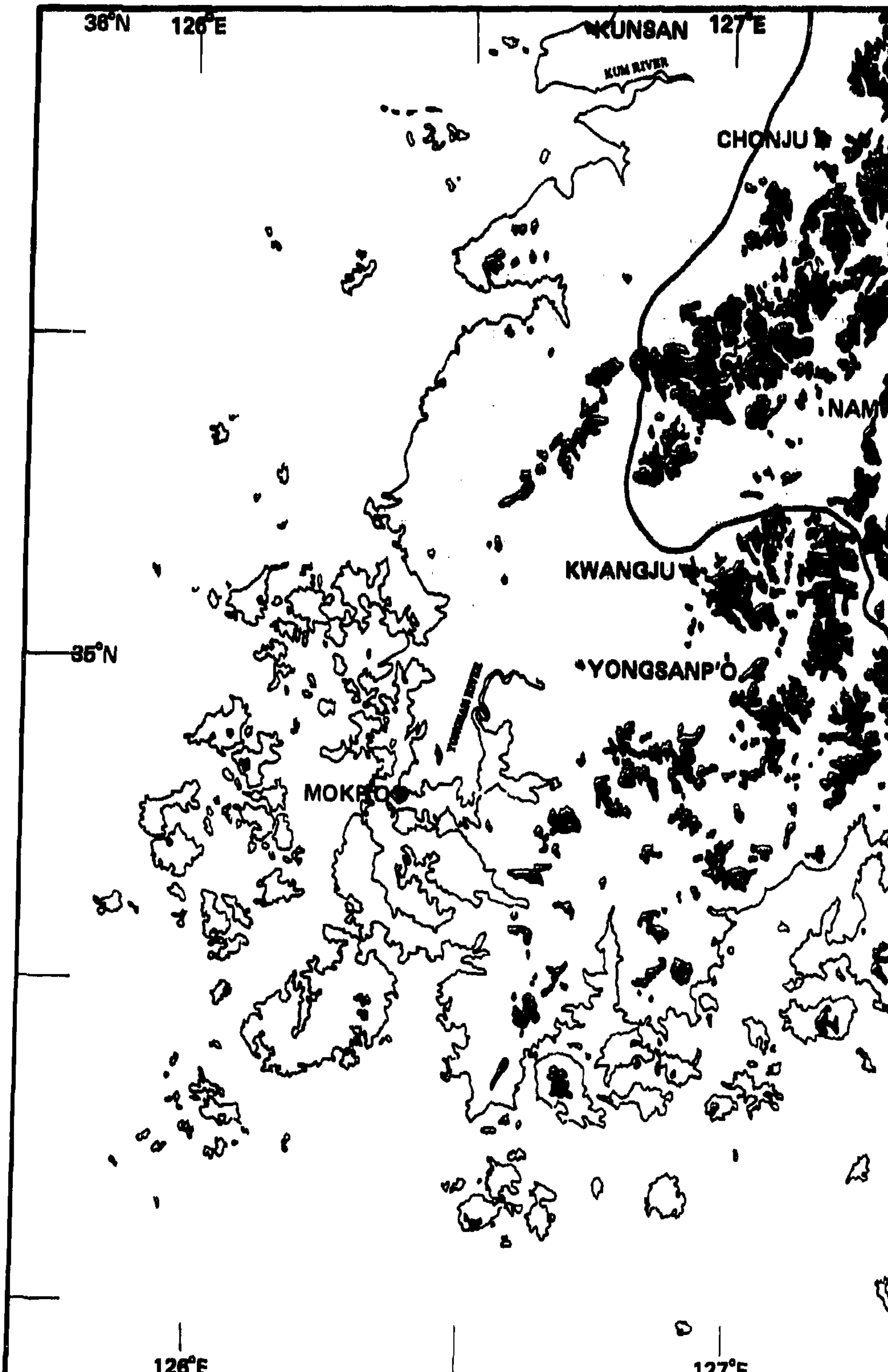


Figure 1-6. DMSP VHR data, 1/3 n mi resolution, on 25 Nov 71 showing the Han River sediment plume entering the Yellow Sea.

Cheju-do province (Figure 1-7), off the southwest coast of Cholla Namdo (South Cholla) province, comprises some 49 islands covering an area of 700 sq mi. Except for nine of these islands, all are mere specks of uninhabited land; only Cheju Island itself has an area exceeding 3 sq mi, and all but 1100 persons of the province's total population live here. Mokpo is the closest port on the mainland and much of Cheju's shipping traffic moves through this port. However, in recent times there has been a marked increase in Cheju's commercial ties with Pusan.

Cheju Island lies 60 mi (96 km) south of the southwest coast and is 35 mi (56 km) from the nearest offshore island. The main towns are Cheju city, Mosulpo, and Sogwipo, a small town on the south coast of the island. Cheju is a volcanic island whose last volcanic activity was recorded in the 17th century. The center of this volcanic activity was Mt. Halla, a centrally located peak which dominates the whole of the island. It rises to 6397 ft (1968 m) some 100 ft (30 m) higher than the highest point on the mainland. It is oval in shape with a circumference of 110 mi (176 km); the slopes are much steeper toward the south than on the north toward Cheju city. A palisade, onto which early lava flows extended beneath the sea, surrounds the island and is the site of Cheju's coral reefs (a rare black type because of the basaltic mud ingested in the coral-making process). It is unusual to find coral at such a northerly latitude (33°N) and the formation is seen as a product of the warm extension of the Kuroshio Current that carries tropical water northwards to Korean shores. The coral reef does not break the surface.



36°N
126°E
KUNSAN
127°E
KUM RIVER
CHONJU
KWANGJU
35°N
YONGSANP'O
MOKPO
126°E
127°E

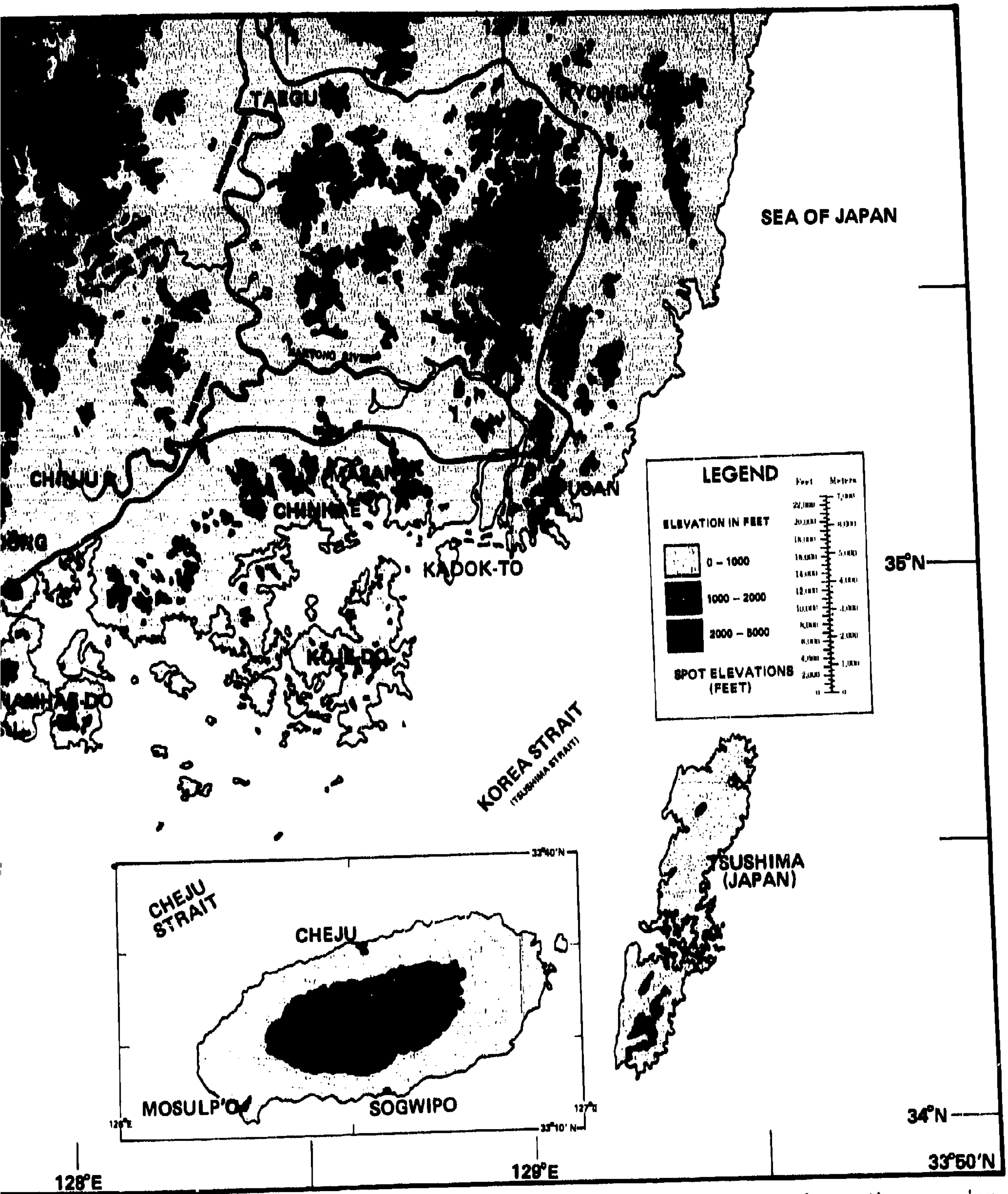


Figure 1-7. Major topographical features of South Korea's southern region.

1.3 THE PROVINCIAL NETWORK

The Republic of Korea is divided into 11 administrative regions consisting of nine provinces and two "special cities" (Figure 1-8). The latter, Seoul and Pusan, were so designated because of their large populations. The nine provinces are: Kyonggi and Kangwon in the north; North and South Kyongsang in the southeast; North and South Cholla in the southwest; North and South Chungchong in the central region; and Cheju Island off the southwest coast. The capitals/administrative centers of the provinces are: Suwon (Kyonggi), Chunchon (Kangwon), Taegu (Kyongsong Pukto/North Kyongsong), Pusan (Kyongsang Namdo/South Kyongsang), Chonju (Cholla Pukto/North Cholla), Kwangju (Cholla Namdo/South Cholla), Chongju (Chungchong Pukto/North Chungchong), Taejon (Chungchong Namdo/South Chungchong), and Cheju city (Cheju-do province).

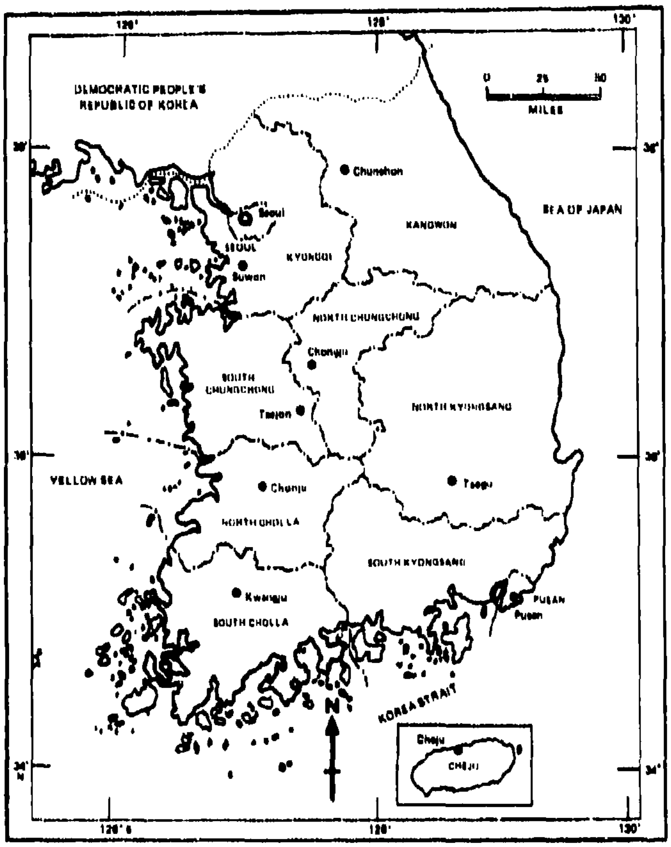


Figure 1-8. The provincial network of South Korea.

SECTION 2

CONTENTS

2. TOPOGRAPHY

2.1 INTRODUCTION

A thorough familiarity with the topography of the Korean Peninsula and the region in which it is located is one of the most important prerequisites to understanding and forecasting local/regional weather. This section describes the topography of East Asia and South Korea; the topography of the sea bottom off the South Korean coast is also depicted (Para. 2.3).

2.2 GENERAL CHARACTERISTICS OF EAST ASIAN AND SOUTH KOREAN TOPOGRAPHY

The western part of China (Figure 2-1) is a high plateau varying from 10,000 to 20,000 ft (3000-6500 m). South of Peiping is the great plain of China, which is broken by several peaks about 3000 ft (1000 m) high near the Shantung Peninsula and a series of ranges south of the Yangtze River averaging 3000-5000 ft (1000-1500 m) high with a few peaks as high as 7000 ft (2200 m). Northeast of Peiping is the Great Basin of Manchuria, a source of exceedingly dry air.

The topography of East Asia may be classified into three types by physical features: the volcanic island area, the eastern ridge line of the continent, and the mountains of central China and Mongolia.

The first major topographical feature is the mountainous wall formed by Japan and the Ryukyu Islands (Figure 2-1), a chain that encloses the eastern edge of the Sea of Japan and East China Sea. The significant barriers to the flow of air in this case are the mountains of Japan which range in elevation* from 5000 to 12,000 ft (1500-3700 m). Along the western coast of Japan, frequent dynamic troughs are produced in the westerly flow and surface fronts often change in intensity.

The second major feature is the eastern ridge line, which rises to approximately 3000-5000 ft (1000-1500 m) along the East Asian coast with a few mountains as high as 8000 ft (2500 m). These are located northeast of Vladivostok and are known as the Khrebet Sikhota Alin range. Just to the north of Vladivostok lie the open plains of the Ussuri River Valley; these are generally below 500 ft (150 m) elevation and are 60 mi (100 km) wide along the coast, forming a natural outlet for northerly winds. To the southwest of Vladivostok, the Nangnim

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*Elevations are referenced to mean sea level (MSL).

mountain range continues into east Manchuria and northern Korea with elevations of 8000 ft (2500 m), thence recurving into central and southern Korea and concentrating along the east coast with elevations of 3000-5000 ft (1000-1500 m).

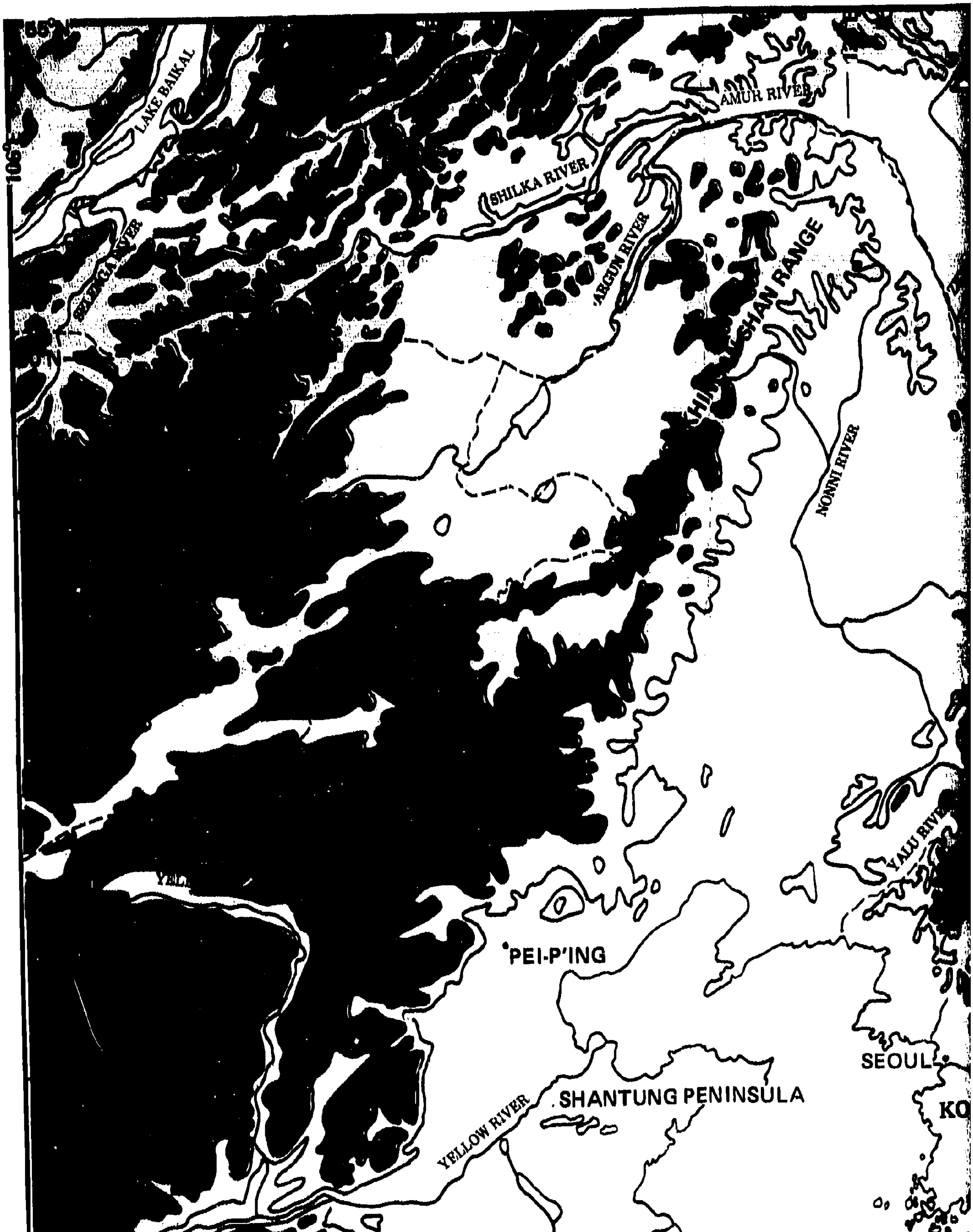
On the Shantung Peninsula, there are several ridges reaching not much more than 3000 ft (1000 m), but still high enough to assist in the development of waves along NE-SW oriented frontal systems. The last range of mountains along the China coast, 4000-8000 ft (1200-2400 m) high, is located north and west of Hong Kong and south of the Yangtze River. Between the Yellow and Yangtze Rivers is the basin of central China where troughs weaken or intensify depending upon the season.

Still another barrier feature is the complex mountain belt in central and north China that is broken only by the two great rivers, Yellow (Hwang Ho) and Yangtze. Just north of these are the very high ranges in western Mongolia that reach 5000-10,000 ft (1500-3000 m); these have a characteristic east-west structure. The system of ranges extending from north China into the northwestern part of Manchuria is called the Takhingan Shan Range and averages 3000-6000 ft (1000-2000 m) in height. Located between the two ranges of Manchuria and Mongolia is Inner Mongolia and the Gobi Desert where strong winds are frequent and an average four inches of rain per year is recorded.

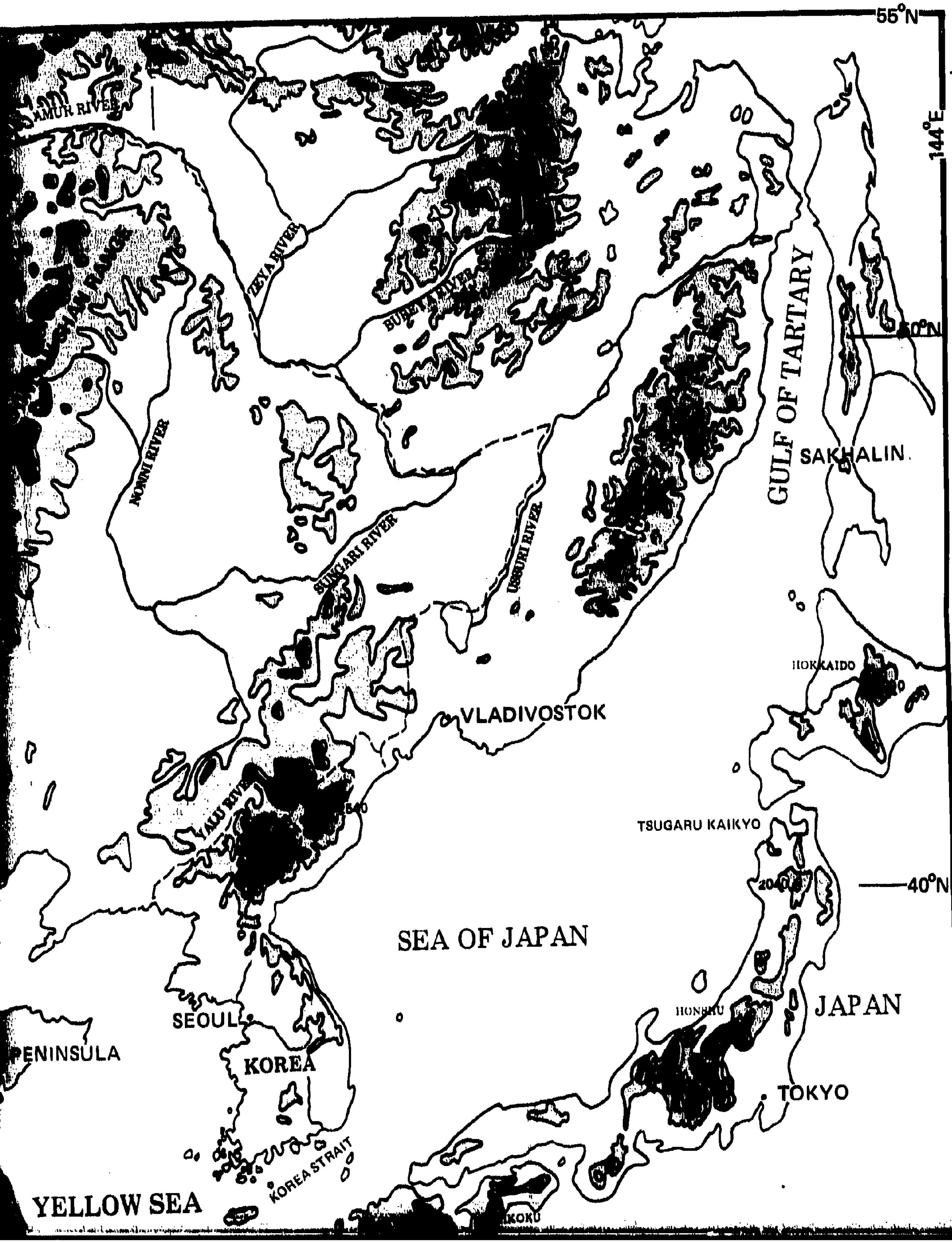
South Korea itself has an abundance of mountain ranges running in all directions (ref. Figure 2-6). In fact, approximately 70% of the total land surface is mountainous with frequently steep-sided slopes that create an intense local relief. Only about 15% of the land can even be considered lowland, and this is almost exclusively the product of erosion; therefore, there are few areas devoid of hills that could be considered "plains" in the sense of the Great Plains of the U.S. midwest. There is no area of lowland so extensive that encircling mountains cannot be seen on a clear day; the largest such area, the Honam Plain in Cholla Pukto, totals only 100 sq mi (161 sq km) (Figure 2-2).

South Korea contains much more lowland than North Korea. Most of these lowlands are located in the western coastal region along the lower courses of the rivers. The significant areas (Figure 2-2) are the Kimpo Plain along the lower Han, a coastal plain along the Sapkyo Chon at Pyongtaek, the Yedang Plain of Northern Chungchung Namdo, the Nonsan Plain north of the Kum River, the Honam Plain of Cholla Pukto, the Yongsan Plain of Cholla Namdo, and the middle reaches of the Naktong River where the valley broadens to about 10 mi (16 km).

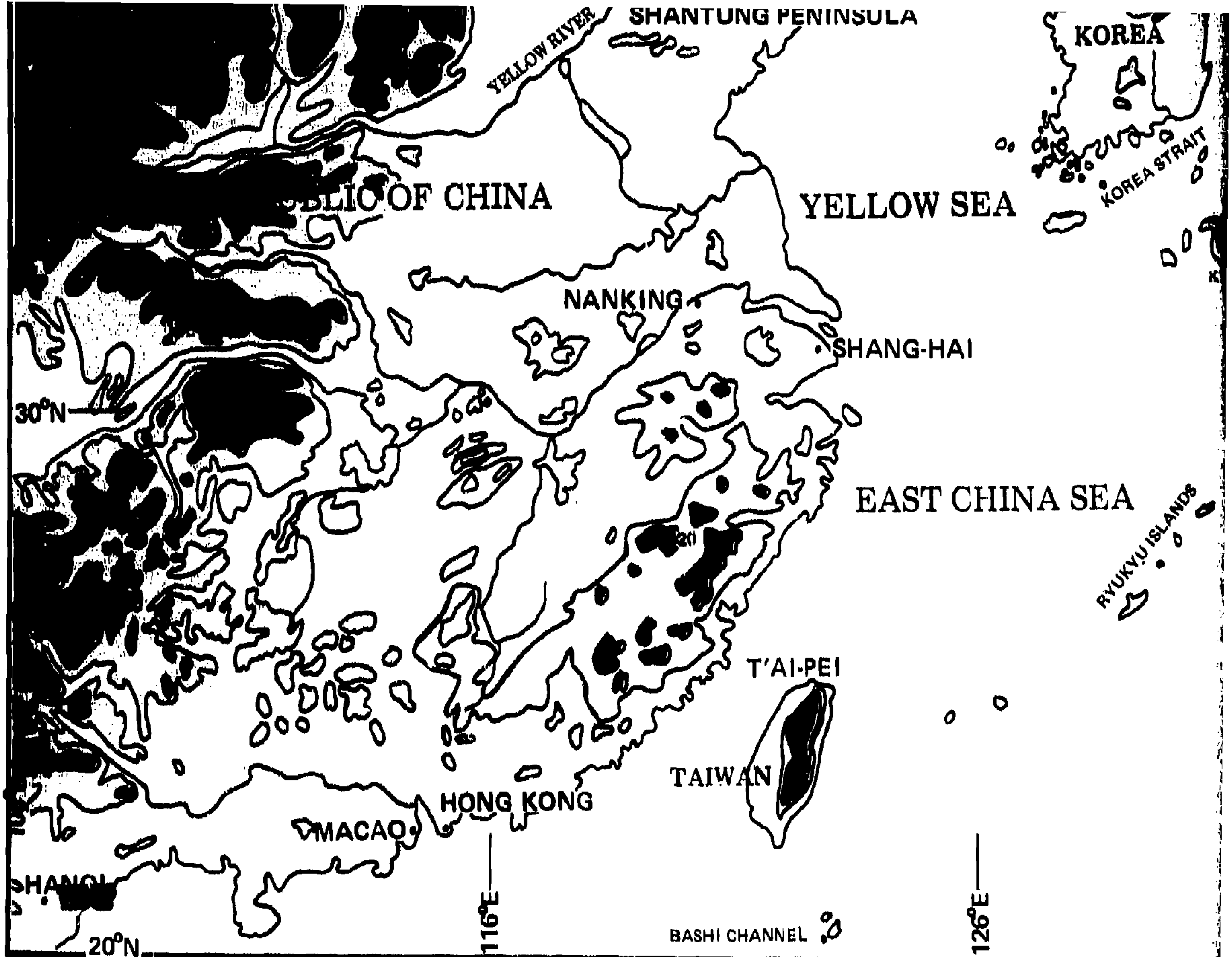
From the watershed divide close to the east coast, the land slopes sharply and abruptly to the narrow and discontinuous lowland of the Eastern Littoral (Figure 2-3). The slope toward the west is much more gradual than that toward the east, and the rivers are relatively long and meandering.



55°N
105°
LAKE BAIKAL
SELENGA RIVER
SHILKA RIVER
AMUR RIVER
ARGUN RIVER
SHAN RANGE
NONNI RIVER
YALU RIVER
PEI-P'ING
SEOUL
SHANTUNG PENINSULA
YELLOW RIVER
YELLOW SEA
OF CHINA



55°N
144°E
50°N
40°N
AMUR RIVER
ZEYA RIVER
BUREYA RIVER
NONNI RIVER
SUNGARI RIVER
USSURI RIVER
YALU RIVER
GULF OF TARTARY
SAKHALIN
HOKKAIDO
VLADIVOSTOK
TSUGARU KAIKYO
SEA OF JAPAN
JAPAN
HONSHU
TOKYO
SEOUL
KOREA
PENINSULA
KOREA STRAIT
YELLOW SEA



SHANTUNG PENINSULA
YELLOW RIVER
KOREA
KOREA STRAIT
OF CHINA
YELLOW SEA
NANKING
SHANG-HAI
30°N
EAST CHINA SEA
RYUKYU ISLANDS
T'AI-PEI
TAIWAN
HONG KONG
MACAO
HANOI
116°E
126°E
BASHI CHANNEL
20°N

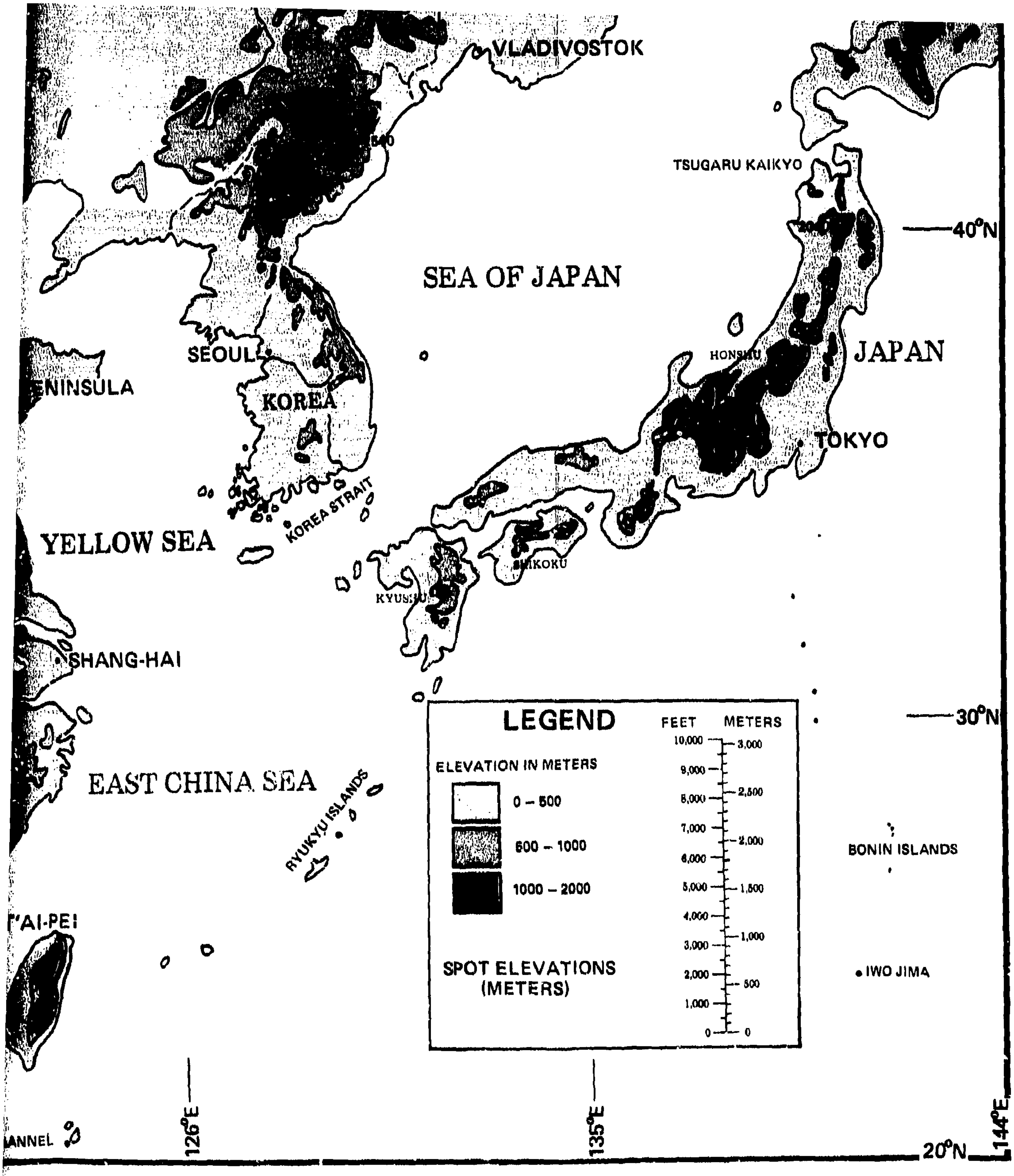


Figure 2-1. Major topographical features of East Asia.

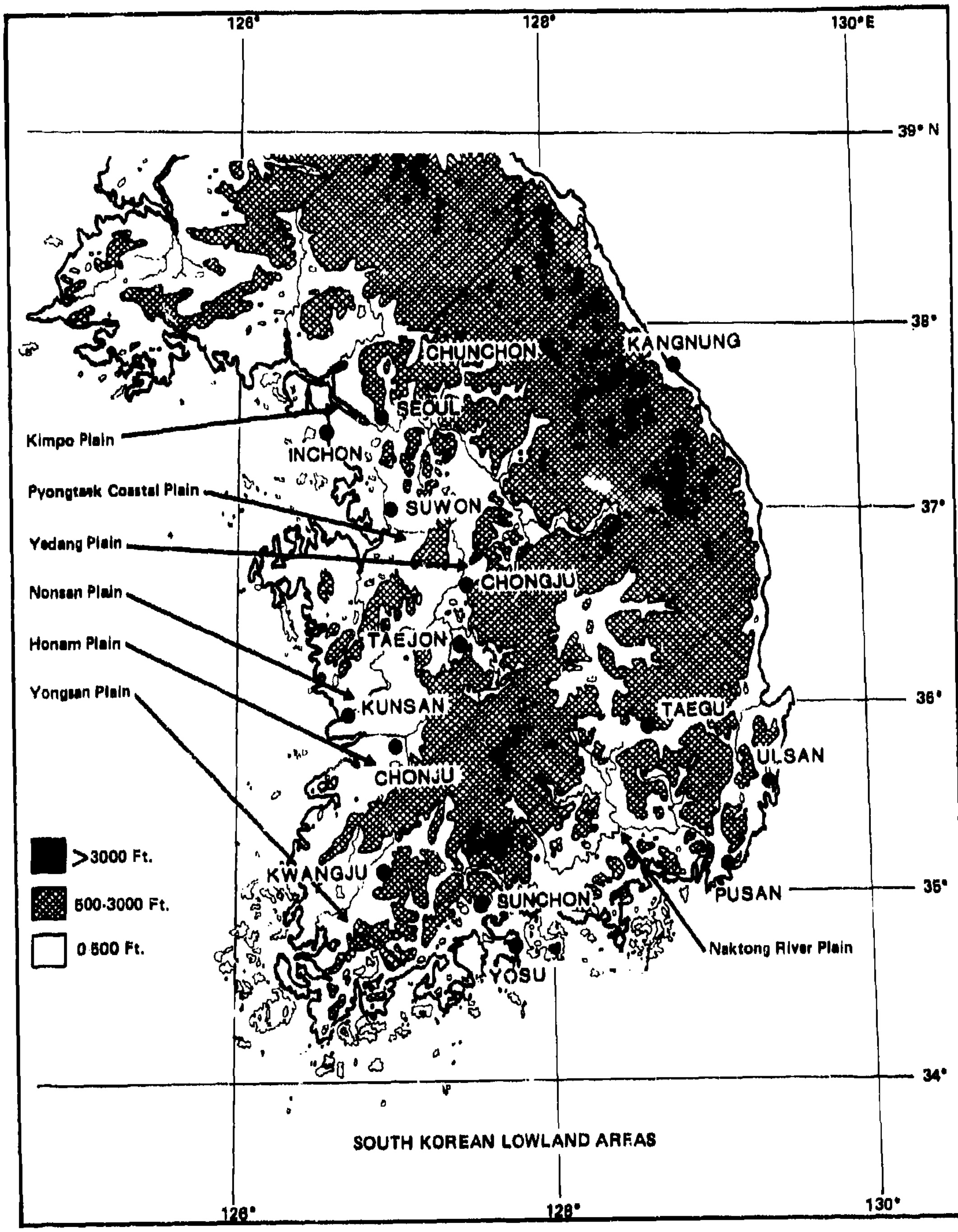
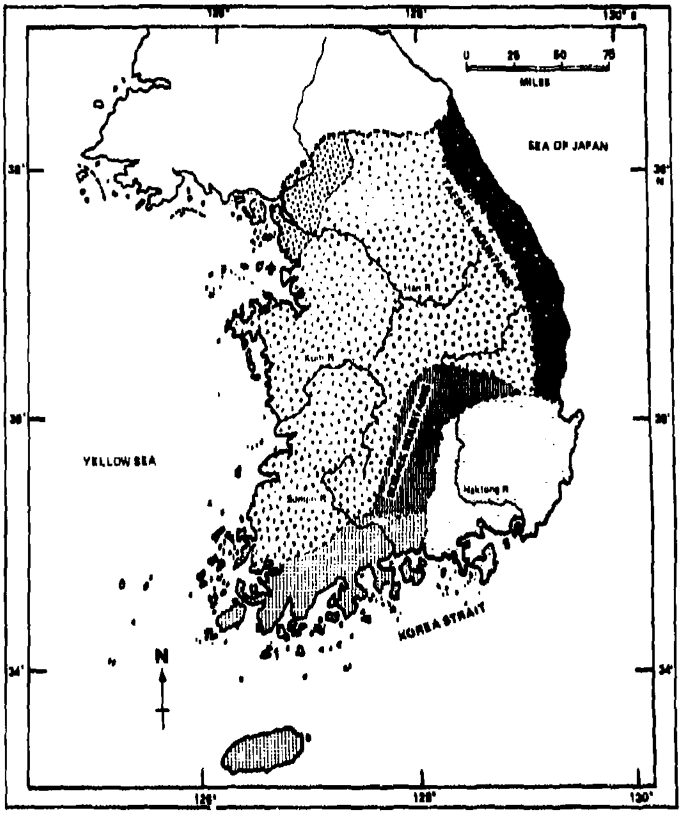


Figure 2-2. South Korean lowland areas.



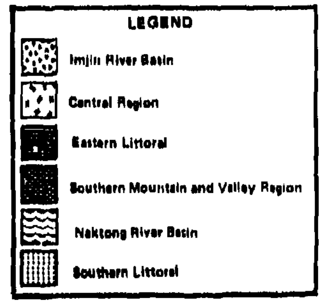


Figure 2-3. South Korea's six major topographical regions.

The mountainous character of the Korean Peninsula lends special importance to the few lowlands and plains -- these have become the primary areas of human habitation and economic activity -- and to the local weather variations that are terrain-induced. South Korean topography is dominated by the Taebaek Mountains, which run parallel and close to the east coast and form the backbone of the Peninsula; other mountain groups branch off from this range like ribs (Para. 2.4).

Fourteen distinct physiographic regions have been identified in South Korea and together they make up the six major topographical regions shown in Figure 2-3.

Of the comparatively large number of rivers and streams, the only four that are of major importance are the Han, Kum, Naktong and Somjin. River flow is highly seasonal, with the heaviest flow occurring during the rainy summer months. Floods are common in the basins associated with the major river systems, particularly in estuarine areas along the west coast. During much of the year, however, the rivers are shallow and expose very wide, gravelly riverbeds.

The 14 physiographic regions of South Korea are described in summary form below and delineated in Figure 2-4.

	Region	Characteristics	Location
1.	Taebaek Mountains	Main east-west watershed, 8-18 mi (13-29 km) from the east coast, rugged. General elevation above 4,500 ft (1372 m).	Northeast in Kangwon-Do and Kyongsang Pukto
2.	Han River Lowlands	Low hills, elevation decreasing westward, a few broad valleys, and the Kimpo Plain.	Seoul-Inchon eastward to Wonju-Chunchon
3.	Imjin River Basin	Mostly in North Korea. North bank part of DMZ.	Northwest of Seoul
4.	Pyongtaek Coastal Plain	Ansong and Sapkyo River Basins. Mostly flat with isolated low hills. Very indented coastline. Tidal flats.	South of Seoul in Kyonggi and northern Chungchong Namdo
5.	Charyong Ranges	Extend southwest from Taebaek Mts. with elevations decreasing from 3,500 to 300 ft (1067-91 m). Broad flat-topped hills.	Northern Chungchong Pukto and central Chungchong Namdo
6.	Kum River	Little alluvial land except near mouth between Nonsan and Kunsan. Estuary silted.	East Cholla Pukto, west Chungchong Pukto and south Chungchong Namdo
7.	Honam Plain	Tongjin- Mangyong River Basins, largest area of level land, rising to hills east of Chonju.	Cholla Pukto
8.	Sobaek Mountains	High mountains of 4,000 ft (1219 m) extending from the Taebaek mountains in northeast to the south coast. Separate southeast from north and west. Terminate in Chiri Massif.	Chungchong Pukto and Kyongsang Pukto, the eastern Chollas and Kyongsang Namdo
9.	Noryong Mountains	Extend southwest from the Sobaek Mts. to terminate in low hills along southwest coast.	Border between North and South Cholla
10.	Yongsan Plain	River basin between the Noryong Mts. and the Chiri Massif. Thousands of islands offshore.	South Cholla

Region	Characteristics	Location
11. Naktong River Basin	East and south of Sobaek Mts. Hilly or mountainous with little level land. Slightly smaller than Han River Basin.	North and South Kyongsang, except for coastal littoral
12. South Coast	Fringe of islands and peninsulas backed by mountains up to 2000 ft (610 m) which block drainage from interior southward and give rise to short coastal streams. Coast of submergence.	South coast, Mokpo to Pusan
13. East Coast	Narrow coastal strip between the Taebaek Mts. and the Sea of Japan. Few embayments and no islands. Broadens south of Yongil Bay. Hyongsan and Taehwa the two main streams. Coast of emergence.	Kangwon, Kyongsang Pukto, Kyongsang Namdo
14. Cheju-Do, Ullung-Do Tokto	Volcanic islands.	Korea Strait, Sea of Japan

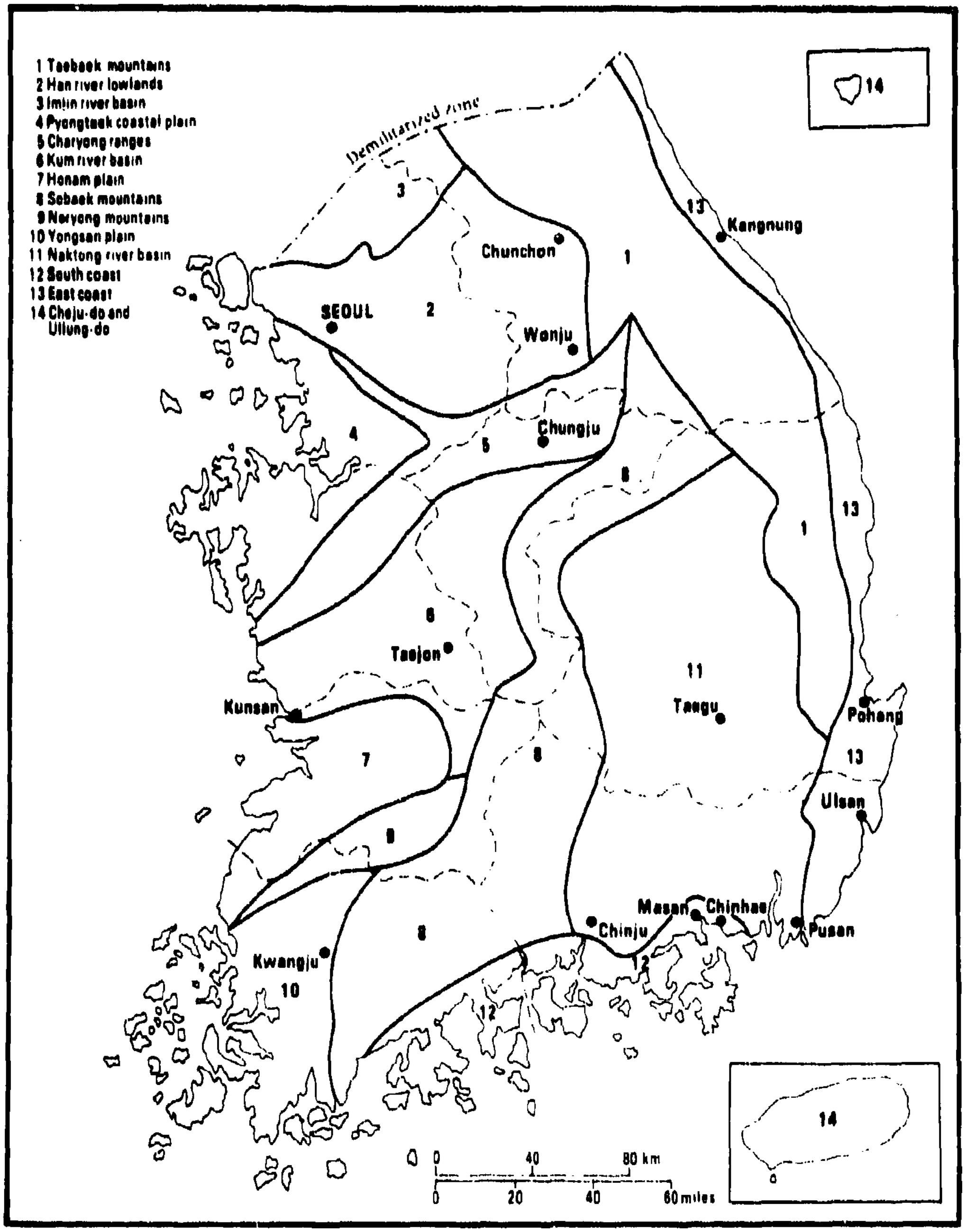


Figure 2-4. Physiographic regions of South Korea (Bartz, 1971).

2.3 SEA BOTTOM TOPOGRAPHY AND SEDIMENT TYPES

Figure 2-5 illustrates the topographic features and sediment types around the coasts of Korea.

LEGEND

Since sharp boundaries are seldom found between ocean sediments, some areas are shown as transitional between major sediment types. In addition, some samples contain several types of sediments, and areas are colored to show these sediment combinations. Some examples of the transitional and combination areas are shown below:

SUB AREAL FEATURES

Land mass with rivers

ALL MARKED DEPTHS IN FATHOMS

MAJOR SEDIMENT TYPES

Mud

Rock and Gravel

Calcareous Mud
(estimated 10-30% calcareous remains)
with sand and silt

Calcareous Ooze and Sand

Sand and Silt

Volcanic Material

Sandy Mud or Muddy Sand

MAP SYMBOL	SEDIMENT TYPE	DEFINITION	COMMON PHRASES USED IN THE LITERATURE TO DESCRIBE THIS SEDIMENT	NOTES AND EXCEPTIONS
4	Sand and silt	Sediments composed predominantly of particles between 2 mm and 4 μ in diameter.	sand silt coarse volcanic ash coral sand Mn micronodules shell sand volcanic glass	Some calcareous oozes may be classified in the literature as sand.
7	Clay	Fine-grained (diameter $<4\mu$) pelagic deposits, $<30\%$ skeletal remains of microorganisms, $<30\%$ $CaCO_3$	clay lutite brown clay red clay gray clay predominant grain size $<4\mu$ brown mud (if sampled at a depth >200m, remote from any continents, in an area where most samples are pelagic sediment) calcareous clay / siliceous clay — unless $>30\%$ Skeletal remains estimated	Samples described as "gray clay" are classified usually as clay but sometimes as mud, depending on the judgment of the data coder. Some reports describe all fine-grained sediments as "clay," while others invariably use the term "mud." Samples described in such a way are generally (but not always) classified according to their description in the source reference, and it is quite likely that some stations numbered 7 should really be numbered 8 and vice versa.
8	Mud	Terrigenous deposits, generally fine grained but may contain significant components of sand or silt sized particles.	black mud blue mud green clay green mud black clay grey clay clay with H_2S or $>.5\%$ organic carbon any samples reported as clay if in shallow water, near shore, in an area where most samples are terrigenous. coral mud volcanic mud volcanic ash	Some authors define mud as a sediment containing at least 20% each of sand-, silt-, and clay-sized particles Some authors (e.g. Revelle, 1944) describe some sediments as "sandy mud" if they are predominantly sand-sized particles of terrigenous origin. Such samples are included in our classification "mud," although they should more properly be classed as "sand"' See notes for clay, above, Some volcanic ash samples are coded as "silt".

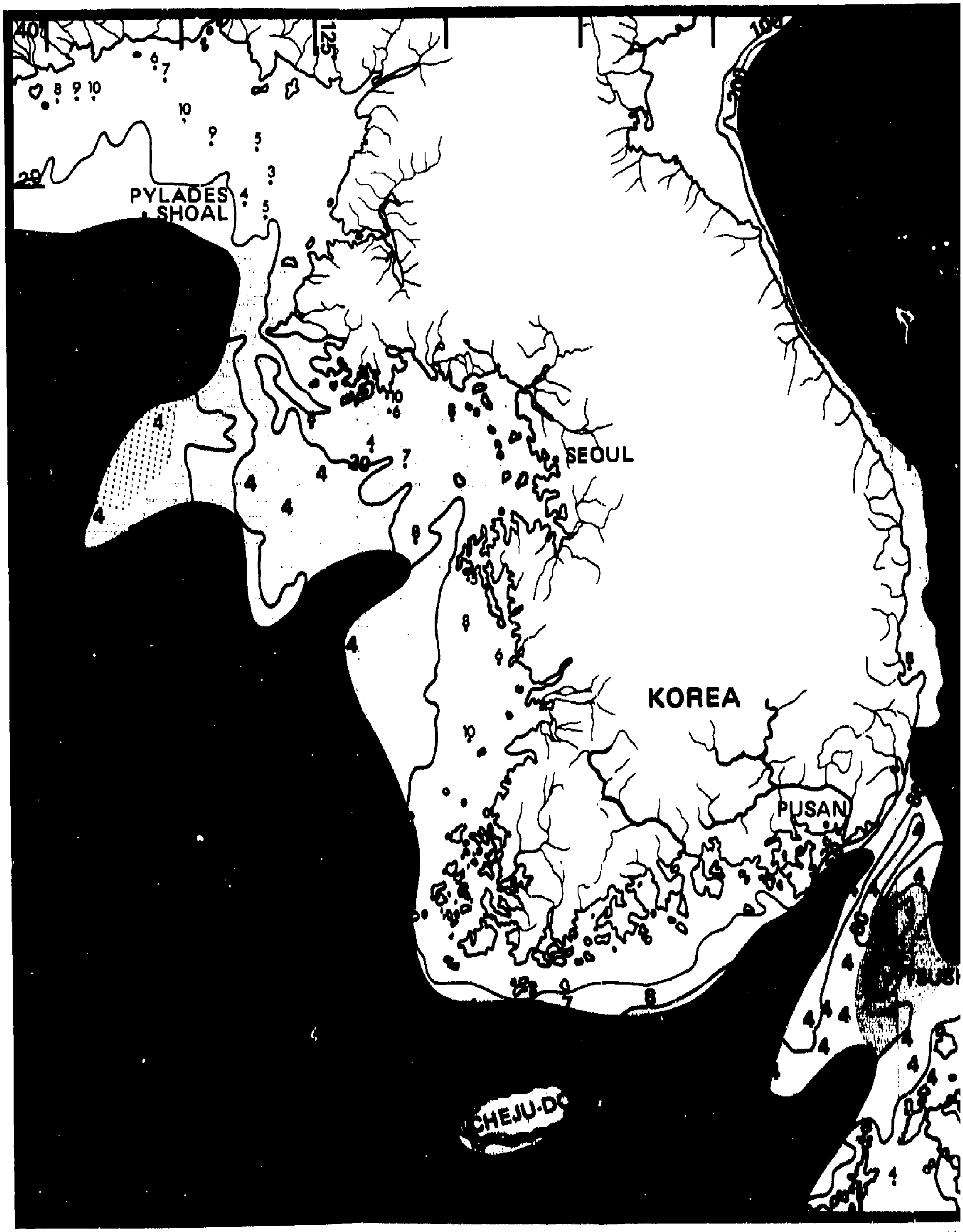


Figure 2-5. Topographical features and major sedi

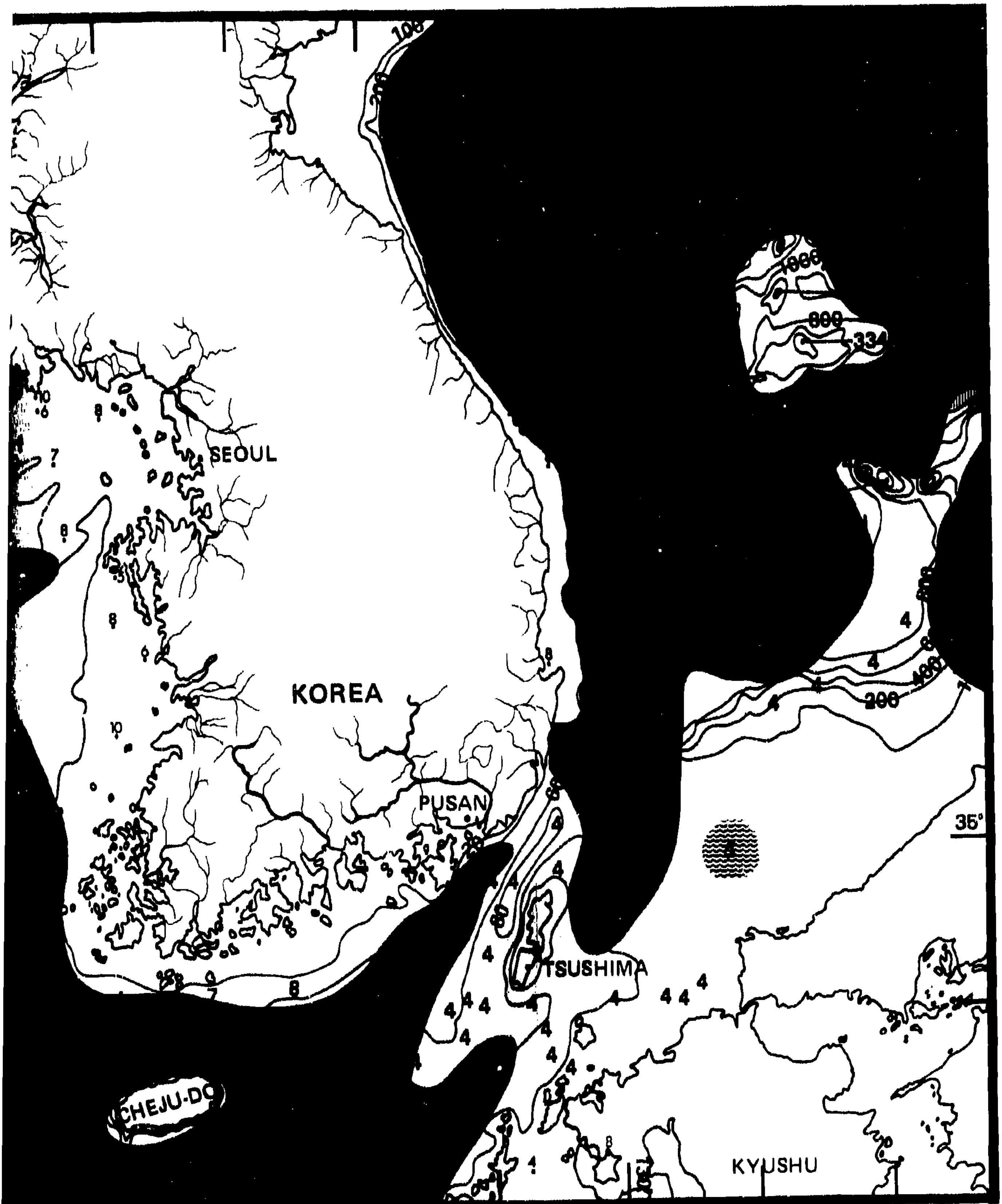
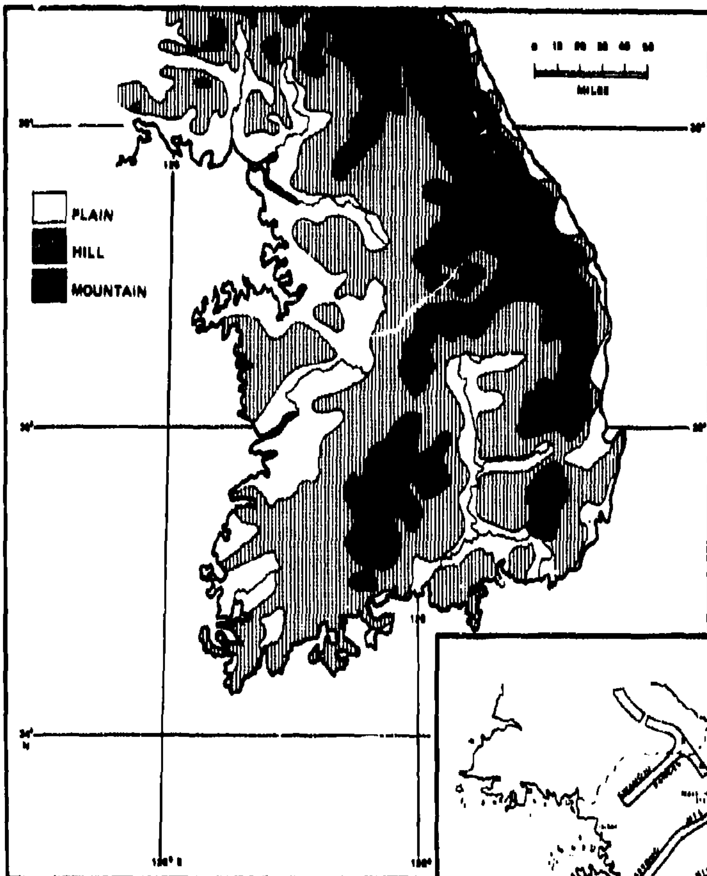


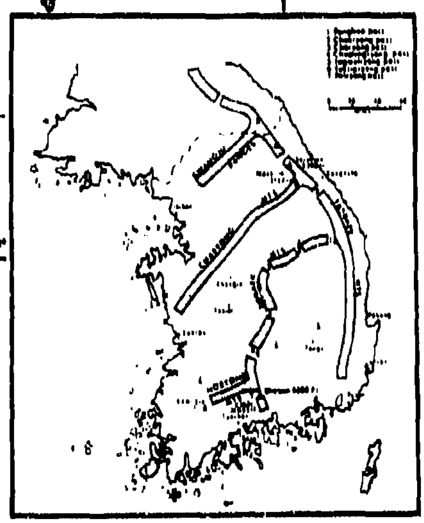
Figure 2-5. Topographical features and major sediment types around the Korean Peninsula.

2.4 SOUTH KOREAN MOUNTAIN RANGES

The seemingly confusing picture of mountains running in all directions (Figure 2-6a) can be simplified by recognizing the five major mountain ridges depicted in Figure 2-6b. Elevations in the hills and mountains generally range from 2000-5000 ft (600-1500 m), with the highest peak on the mainland, Chirisan, reaching 6283 ft (1933 m). Slopes in the hills range from 10% near valley bottoms to 30% near the summits. Mountain slopes tend to be very steep, commonly between 30% and 70%. Low vegetation consisting mainly of shrubs, stunted trees and scattered grassy areas is the main ground cover on the hills and mountains.



a.



b.

Figure 2-6. Mountain ranges of South Korea:
(a) elevations and (b) range diagram.

2.4.1 Taebaek Mountains

This range of high mountains roughly parallels the east coast; its crests approximately 10 mi (16 km) inland constitute what is often called the "mountainous backbone of the country." The range extends south from the DMZ to near Pohang, a distance of some 160 mi (256 km). Soraksan, north of the 39th Parallel (Figure 2-7), has the highest peak in the range (5603 ft/1725 m); another high peak, Odaesan, lies just 20 mi (32 km) to the south. Two east-west branches, the Charyong and Sobaek ranges, extend from this eastern range.

2.4.2 Charyong Mountains

Starting from Odaesan in Kangwon-Do, the Charyong range forms the boundary between Kyonggi and North Chungchong provinces and continues southwest through South Chungchong to reach the west coast just northeast of Kunsan (Figure 2-8).

The elevation decreases westward from 3500 ft (1067 m) in Chungchong Pukto to 1000-2000 ft (300-600 m) in Chungchong Namdo. Mt. Songju 6 mi (10 km) from the Yellow Sea rises to almost 2300 ft (700 m). The Charyong Mountains are not high enough to act as a major watershed or obstacle to transportation, but they do separate the drainage of the coastal plain south of Seoul from that of the Kum River Basin. A small offshoot of the Charyong extending from Chongju northwest toward Seoul separates the coastal rivers near Ansong from the Han River Basin in which Seoul is located.

2.4.3 Kwangju Mountains

The Kwangju range, an offshoot of the Taebaek Mountains, extends southwest to include the mountains around Seoul (Figure 2-8). The range separates the Paju plain in the Imjin drainage from the Han and includes such well-known peaks as Tobongsan, 2352 ft (723 m); Suraksan, 2011 ft (618 m); Pukhansan, 2743 ft (845 m); and to the south of Seoul, Kwanaksan, 2064 ft (635 m) and Namhansan, 1987 ft (611 m).

2.4.4 Sobaek Mountains

The southern mountain and valley region is dominated by the Sobaek Mountains, which extend southwestward from the southern end of the Taebaek range. The Sobaek range separates into a series of parallel ridges and valleys that extend to a complex of coastal indentations and offshore islands at the southwestern tip of the country (Figure 2-9).

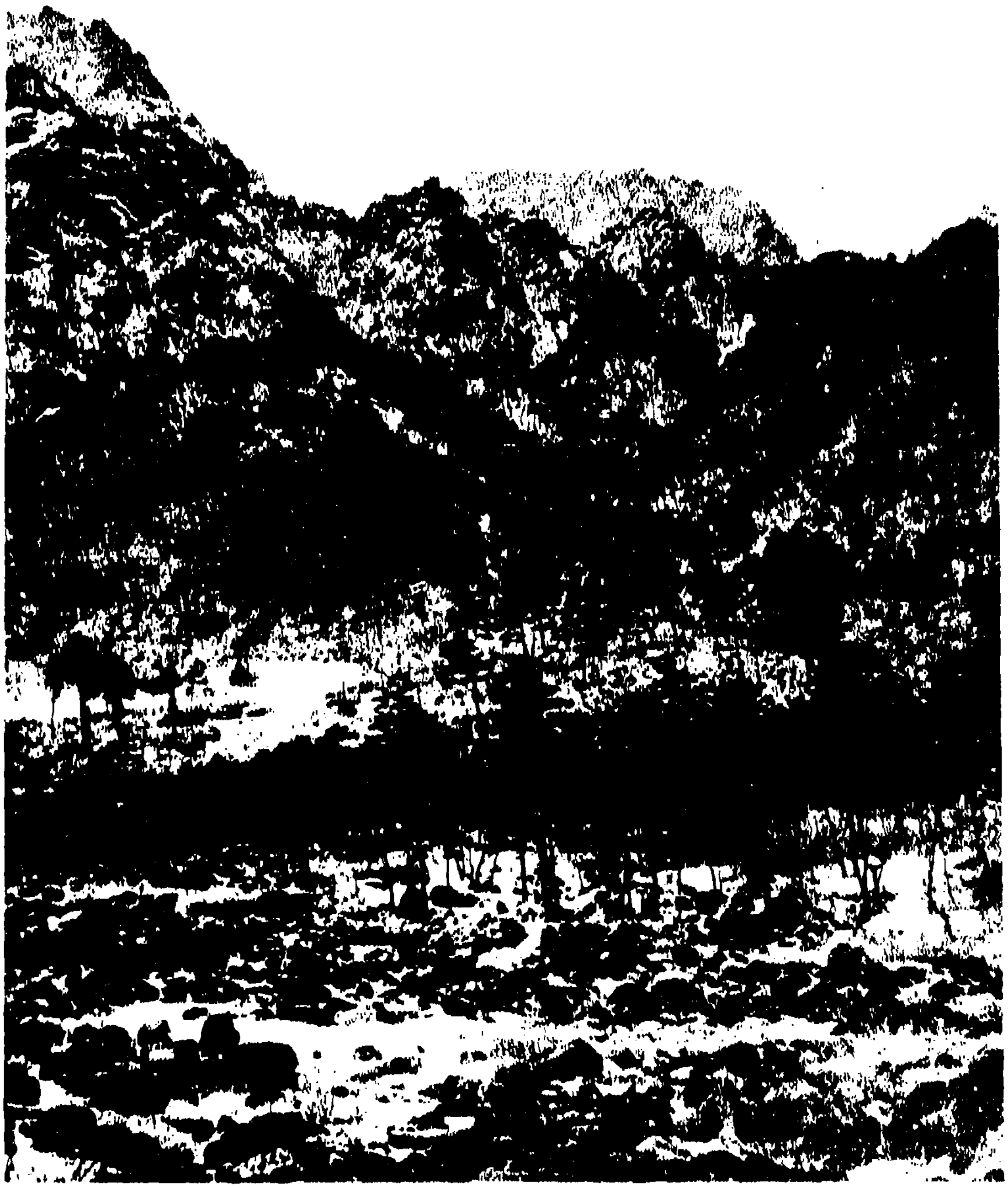


Figure 2-7. Mt. Soraksan, height 5603 ft/1725 m (Bartz, 1971).

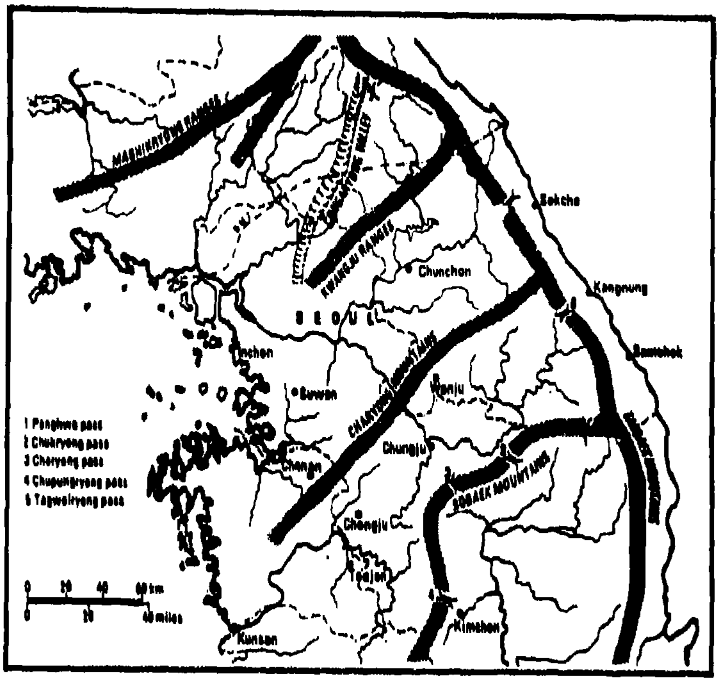
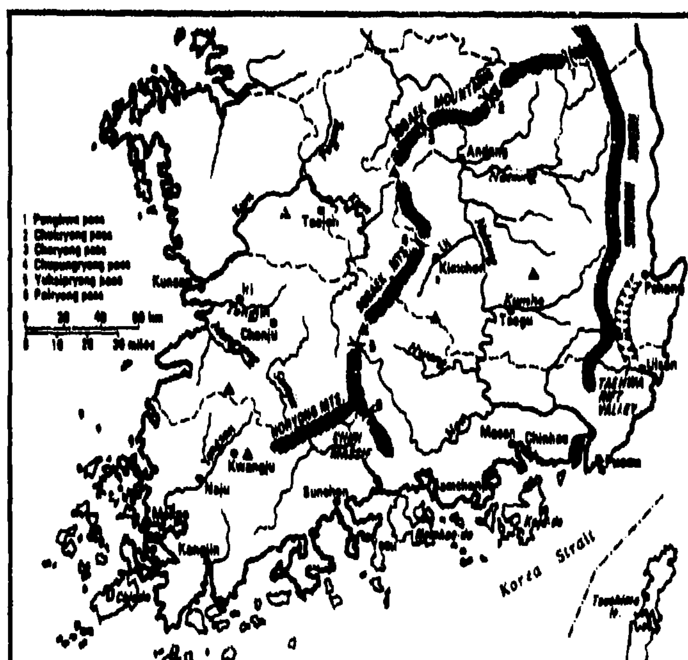


Figure 2-8. Mountain ranges and passes in the northern and central regions of South Korea (after Bartz, 1971).

Figure 2-9. Mountain ranges and passes in the southern region of South Korea (after Bartz, 1971).



The mountains form an interior divide, separating the northwest area and Seoul from the southeast area and Pusan. In the south, the Sobaek range terminates in the great Chiri Massif that extends over three provinces and occupies an area of some 60 sq mi (96 sq km). Here the highest peak (second highest in South Korea) rises to 6283 ft (1933 m). The Sobaek range has a general elevation of 3500 ft (1075 m) and thus presents a real obstacle to movement across the southern part of the Peninsula.

2.4.5 Noryong Mountains

The Noryong range, an offshoot of the Sobaek, extends southwest along the border between North and South Cholla (Figure 2-9). These mountains rise only to 2500 ft (762 m) and form a natural boundary between the Honam plain and the Yongsan River basin.

2.5 REGIONAL TOPOGRAPHY

2.5.1 The North: Kyonggi and Kangwon Provinces

These two northernmost provinces border the DMZ and encompass the whole of the Han River basin, the Han-Imjin estuary, the islands adjoining the Ongjin Peninsula and the capital of Seoul (Figures 2-10, 2-11).

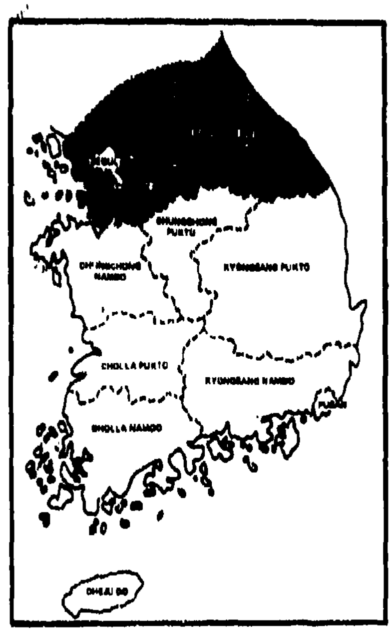


Figure 2-10. The northern provinces.

Kyonggi comprises a number of lowland areas separated by mountain or hill ridges. Half the province has an elevation below 330 ft (101 m) in lowlands found in the Paju plain near Munsan, the Yoju lowland along the South Han, the Kimpo plain northwest of Seoul (location of Kimpo Airport, Seoul's international air terminal) and the coastal lowlands near Pyongtaek (Figure 2-11).

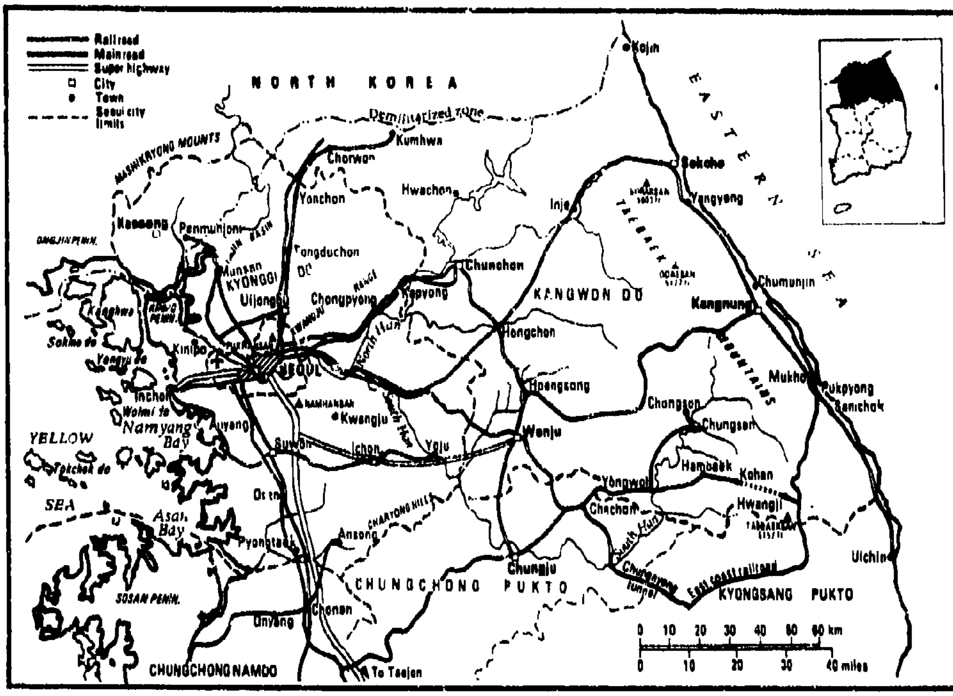


Figure 2-11. Kyonggi and Kangwon provinces.

The Kwangju Mountains extend southwest from the northeastern corner of the country and around Seoul (ref. Figure 2-8). Southeast of Seoul, the Charyong range separates the Han drainage from a number of small basins. The topography is markedly less rugged to the south and west of Seoul than to the north and northeast.

Kangwon is the most mountainous of all the provinces with 8% of the land above 3250 ft (1000 m) and only 9% available as arable land. Soraksan, at 5603 ft (1725 m) in the Taebaek range, is the highest peak in the province and the third highest in all of South Korea.

The Taebaek Mountains run southward through the province in close proximity to the coast, terminating near Pohang. The highest elevations in the eastern part of the range (thus closest to the east coast) are generally 4000-5000 ft (1230-1538 m). Dissection has produced steep slopes and spectacular, rugged scenery. Approximately 30 mi (48 km) west of Kangnung is Odaesan (5127 ft/1563 m), the source of the headwaters of the South Han. The principal pass across the mountains is at Tagwolryong approximately 20 mi (32 km) west of Kangnung.

2.5.2 The Southeast: Kyongsang Pukto and Namdo

Kyongsang Pukto (Figures 2-12, 2-13) is the largest of all the provinces. Its northern boundary lies within the ridge of the Sobaek Mountains, which effectively separate the province from its adjoining provinces to the north and west. East-west movement is facilitated by a number of low passes. The Naktong River flows along the northern boundary of the province and loops southward to form an extensive delta and enter the sea in a fault valley just west of Pusan. The eastern part of the province is dominated by the Taebaek Mountains. The general elevation here of 2500 ft (770 m) is somewhat lower than to the north in Kangwon.

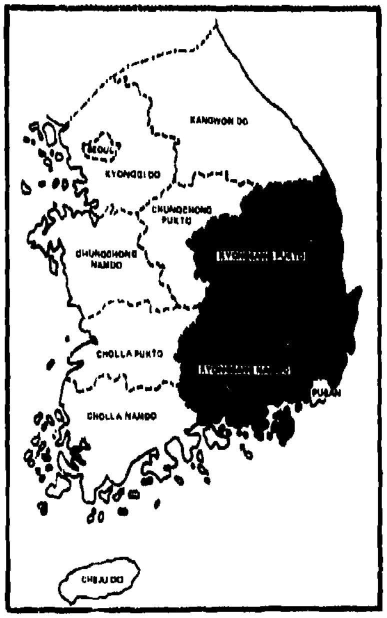


Figure 2-12. The southeastern provinces.

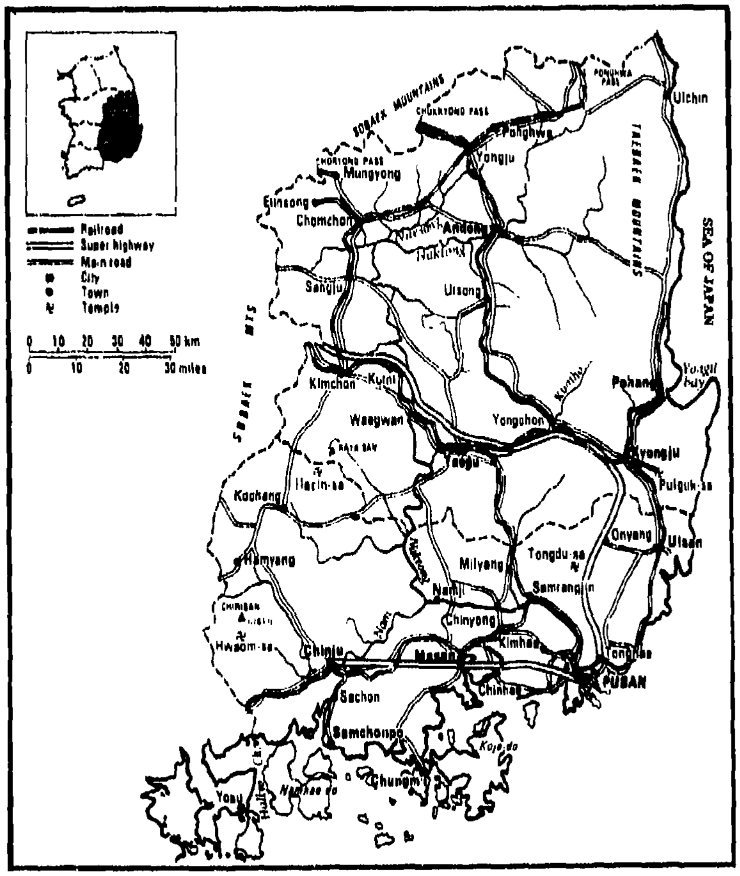


Figure 2-13. Kyongsang Namdo and Kyongsang Pukto provinces (after Bartz, 1971).

The rivers in this area do not have sufficient velocity to transport the sediment washed into them from the largely deforested hills, and deposition into the river beds has raised their levels above the valley floors in some cases. This factor, in periods with significant runoff from the summer rains, has increasingly created flood hazards.

Kyongsang Namdo (Figure 2-12, 2-13) is bounded on the west by the mountains of the Chiri Massif which occupy a quarter of the province's area. The highest peak in the Chiri Massif is Chirisan, 6283 ft (1930 m); it is situated close to the point where three provinces, the two Chollas and Kyongsang Namdo, meet.

The mountains in this area are markedly steep because of the sedimentary nature of the rocks and the ease with which rivers can cut into such rocks. West of the Naktong, between Pusan and Chinju, the steepness of the mountain slopes has given rise to more terracing than elsewhere in South Korea. In the event of heavy rains, whole expanses of these terraces can be scoured off the hillside; then the valley floors, with their very slight gradient toward the Naktong, become flooded.

East of the Naktong valley, a series of low hills separates the river basin from a small coastal strip that reaches from Pusan north towards Ulsan and Pohang. The principal river in this area is the Taehwa, which drains east to the coast at Ulsan and provides much of Ulsan's water supply. The main topographic feature is a north-south rift valley extending from Ulsan almost to Kyongju (ref. Figure 2-9). East of this valley is another series of low hills rising to 1400-2000 ft (430-615 m) in such peaks as Muryongsan and Tongdaesan; these hills constitute the last of the low, outlying, high ground of the Taebaek Mountains.

2.5.3 The Southwest: The Chollas and Cheju-Do

Cholla Pukto (North Chollo; Figures 2-14, 2-15) is a mixture of mountainous terrain to the east and the Honam plain to the west. This plain, the largest in South Korea, stretches from the Kum River in the north to the Naryong Mountains along the southern border.

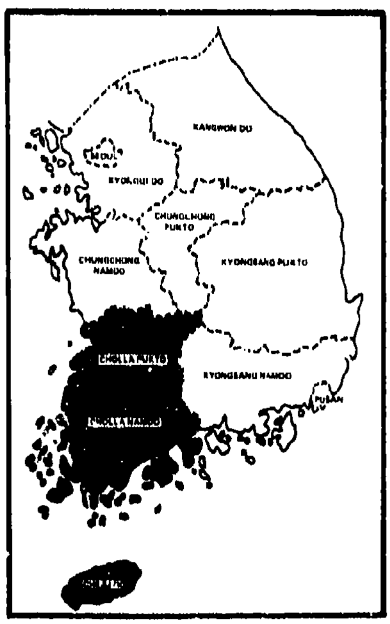


Figure 2-14. The southwestern provinces.

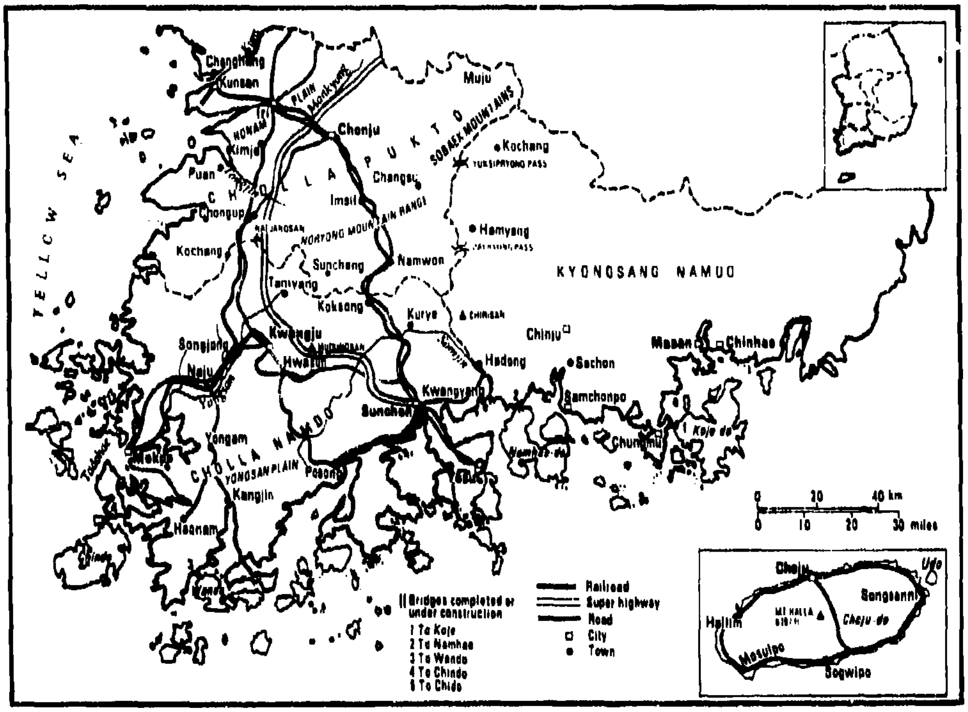


Figure 2-15. Chollo Pukto, Chollo Namdo and Cheju provinces (after Bartz, 1971).

To the east and south, the plain is bordered by the Naryong Mountains which stretch northeast and then southwest across the central and southern part of the province. These mountains have a lower general elevation than the Sobaek Mountains located further to the east (see Para. 2.4.5). There are some high peaks, however, with Unjangsan at 3704 ft (1129 m) the best known. The Sobaek Mountains, with peaks such as Togyusan rising to 4500 ft (1372 m), provide a natural boundary with Kyongsang Namdo.

The Sobaek Mountains terminate in the Chiri Massif (see Para. 2.4.4), which rises in steps with cultivated plateaus and valleys between the peaks. The Sobaek and the Noryong ranges are dissected by the branches and main stems of the Kum River in the north and the Somjin River in the south. Between these streams, many swollen rivers such as the Mangyong and Tongjin dissect the countryside. The estuary of the Tongjin has recently been blocked off in a large reclamation project. The Kum River originates near Changsu, flows north with many small tributaries, and then turns west for a large part of its course to form a boundary with Chungchong Namdo. Its estuary at Kunsan silts up at a rapid rate. The Somjin River, which drains the Chiri Massif to the south coast, enters the sea at Kwangyang Bay in Cholla Namdo (South Chollo, Figure 2-15).

Cholla Namdo is bordered to the north and east by mountains, to the west by the Yellow Sea and to the south by the Korea Strait. Near Namwon in Cholla Pukto, the Sobaek Mountains split into a northerly arm, the Naryong range, which provides the northern boundary to the province, and an eastern arm, the Chiri range, which provides an eastern boundary.

These mountains are dissected by many small streams, creating well-known individual peaks. The most famous of these is Mudungsan which rises to 3894 ft (1200 m) directly east of Kwangju. The central part of the province is occupied by the Yongsan plain on which Kwangju, Naju and Mokpo are located.

The Yongsan River, fifth largest in South Korea, has an extremely variable flow and is tidal as far inland as Naju. In times of drought, there is little natural flow and saltwater takes over the lower channel. However, late summer storms generated by the southward-moving polar front produce torrential rainfalls of up to 12 inches in one day as they rise to cross the Chiri Massif and flood adjacent land. The other large river, the Somjin, rises in Cholla Pukto and sweeps southward to enter the Korea Strait rather than the Yellow Sea. Unlike the Yongsan, it flows through a narrow winding valley in the foothills of the Chiri Massif and enters the sea near Hadong. The Tamjin, a short local stream, enters the Korea Strait through a long, shallow, winding estuary known as Kangjin Bay. It is proposed to reclaim the Yongsan and Tanjin estuaries behind dikes.

2.5.4 The Central Region: Chungchong Pukto and Namdo

The Chungchong provinces (Figures 2-16, 2-17) form the central segment of South Korea; they stretch inland from the west coast towards the Taebaek Mountains in the northeast and the Sobaek Mountains to the south. The low Charyong range forms a boundary to the north and the watershed between the Naktong and Kum Rivers forms the boundary in the east. The width of the Kum River creates a natural boundary in the south (Figure 2-17). Chungchong Pukto is South Korea's only completely landlocked province. In the northeast beyond Tanyang, the terrain is the most formidable in the country.

The Charyong range in the northern sector of Chungchong Pukto (North Chungchong) can be roughly divided at Chungju between an eastern section of rugged topography and a western section of low, dissected hills. Although the eastern section has peaks over 3000 ft (923 m), the elevation drops away quite dramatically beyond the South Han. The second mountain range of the province, the Sobaek, is much wider and higher than the Charyong. Kurmangbong, at 4614 ft (1420 m), is the highest peak. Drainage westward from the Sobaek Mountains is to the Kum River. The Kum rises in Cholla Pukto and flows north through Chungchong Pukto, following a meandering path as it seeks a course through the mountain ridges toward the Yellow Sea.

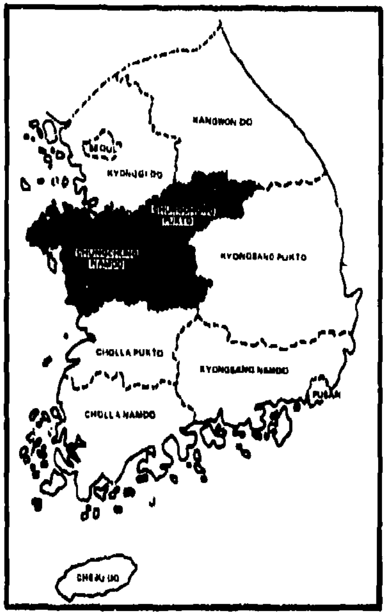


Figure 2-16. The central provinces.

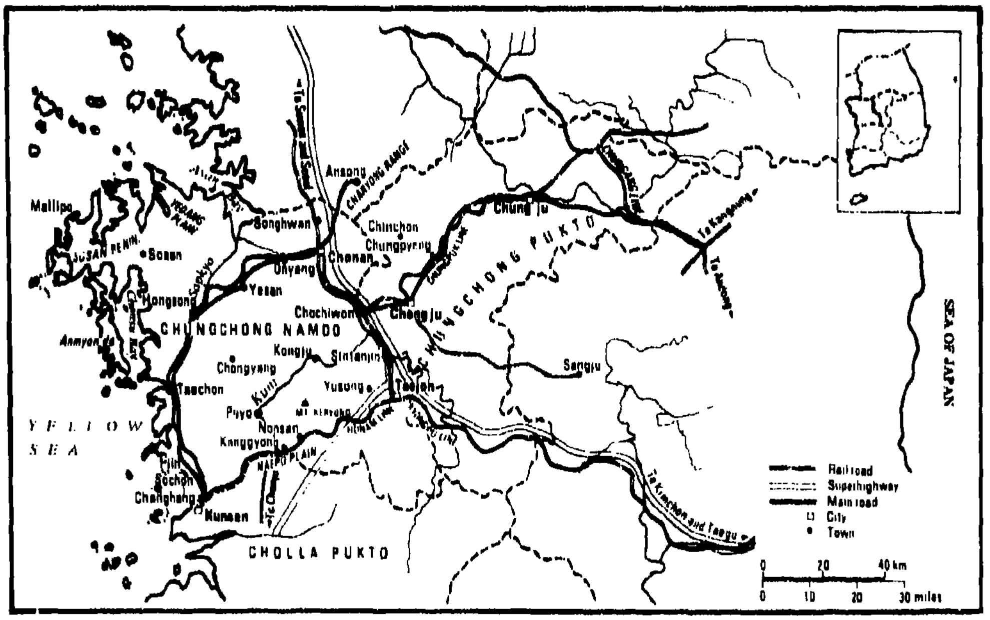


Figure 2-17. Chungchong Pukto and Chungchong Namdo provinces (after Bartz, 1971).

There are very few pockets of alluvial land along its main stream and tributaries, the biggest being the Miho plain on which Chongju is located. The largest area of alluvial land (plain) within the province is along the South Han around Chungju where the river is met by its main tributary, the Dal Chon. The province is a land of high valleys with less than 10% of its land below 330 ft (100 m).

Although Chungchong Namdo has the lowest average elevation of any province in South Korea, it still has mountains. The Charyong range runs across the central part of the province with an elevation generally less than 2000 ft (615 m). The Kum, the third largest river in the country, has a total length of about 240 mi (384 km), half of it in this province. Across the Kum, in the southeastern part of the province near Taejon, are several mountains of greater elevation than the Charyong. These are outliers of the Sobaek range; the highest and best known peak in the province is Mt. Keryong at 2716 ft (836 m).

SECTION 3

CONTENTS

3. CLIMATE

3.1 INTRODUCTION

This section describes the climate of the Korean Peninsula and summarizes the available climatology for various meteorological and oceanographic elements. The inherent variability of any climatic element makes it difficult to project future conditions for a specific time other than in terms of probabilities. Nevertheless, is is important to be aware of the given climatology to ensure that the climatic extremes, the regional differences and the seasonal differences are taken into account in any operational plan.

Mean or average climatic conditions are seldom representative of the actual conditions that can be experienced on any particular day, so these data should be used cautiously in projecting possible climatic conditions at a given time and location. Inclusion of such data within this section is primarily intended to emphasize the seasonal and regional differences that occur across the Peninsula.

More detailed climatic data are available in Climatic Summaries for Major Seventh Fleet Ports and Waters, the U.S. Naval Weather Service Command's summaries of synoptic meteorological observations for areas 25-29 incl.; Air Weather Service pamphlet 105-4, Vol. VII*; the Climatic Atlas of Korea 1931-1960, published by the Central Meteorological Office, Seoul; and Climate of Korea, 1st Weather Wing Special Study 105-2.

More detailed information on ocean data -- monthly mean temperatures and salinities from the surface down to 400 ft (122 m) -- can be obtained from the 1976 Department of the Navy North Pacific Ocean Atlas, National Oceanographic Office Reference Publication 2.

3.2 THE FOUR SEASONS

The Korean Peninsula lies within the Asiatic monsoon** circulation and experiences hot, short, humid summers and long, cold, dry winters. The coldness

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*AWS pamphlet 105-4 is undergoing revision; at the time of writing, it is not known when the revised version will be distributed.

**The monsoon has been defined by Ramage (1971) as follows: (1) The prevailing wind direction shifts by at least 120° between January and July; (2) the average frequency of prevailing wind directions in both January and July exceeds 40%; and (3) the mean resultant winds in at least one of the two months (January or July) exceeds 6 kt.

of the winter (maximum 32°F on a typical January day) might suggest that the country is much further north than it actually is. At 37°N, Seoul is more than 300 mi (483 km) closer to the equator than are London or Paris, and is in approximately the same latitude as Washington, D.C., San Francisco, and Athens, Greece (see Table 3-1). Spring and fall generally represent the transitional periods between the dominant monsoon regimes. Other important climatic controls that supplement the monsoon regime are the migratory systems that pass over or near the country, the varied terrain, and the adjacent seas and nearshore currents.

Table 3-1. Temperatures at Seoul and cities of comparable latitude (mean monthly temperatures °F).

City	Lat.°N	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seoul	37°34'	24	30	40	53	63	70	78	79	69	57	44	31
Wash. D.C.	38°55'	33	35	45	53	64	72	77	75	68	57	45	37
Tokyo	35°41'	37	38	41	54	62	69	75	76	72	61	50	41
Athens	37°48'	46	48	52	59	68	76	80	80	74	66	57	50
San Fran.	37°45'	50	52	54	55	57	59	59	59	61	61	56	51

3.2.1 <u>Winter: November through March</u>

Winter weather is dominated by a high pressure area caused by the intense cold over Siberia. In January, this Siberian high is more intense than at any other time of the year. Cold, dry air flows southward from the high along the east coast of the Asian mainland, pushing as far south as the northern Philippines. The outermost edge of this cold air, where it borders the warm moist air masses that have originated over the tropical oceans, is called the polar front. The mean locations of these features for February are shown in Figure 3-1.

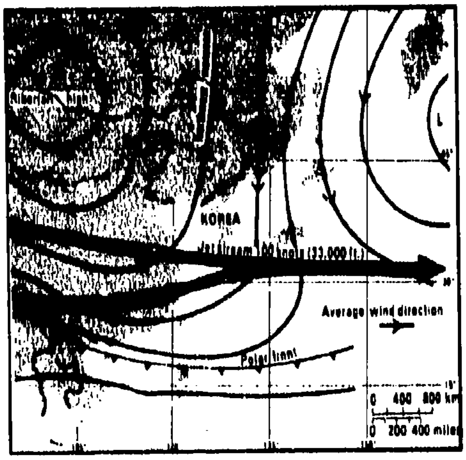


Figure 3-1. February mean pressure and wind systems (from 1st Weather Wing, USAF).

The clockwise circulation of air around the dominant high pressure area gives rise to northerly or northwesterly winds that are referred to as the northwest monsoon. The air transported by this system gives South Korea below-freezing temperatures in late December and throughout January and February. The surface soil remains frozen until the end of January along the southern coast; it generally begins to thaw at Seoul about the end of February.

Although the northwest monsoon is the predominant feature of the winter weather, small low pressure areas occasionally form in the East China Sea near Taiwan (as a result of irregularities or waves on the polar front) and work their way northward to bring cloudiness and precipitation. Other small low pressure areas known as Shanghai lows form over the relatively warmer Yellow Sea and then pass eastward over the Korean Peninsula; with the passage of one of these, the winds along the east coast become more northeasterly, acquire moisture over the Sea of Japan, and bring heavy snowfalls to the Taebaek Mountains and the east coast north of Kangnung. On exceptionally cold nights, low clouds may form to the west over the warmer Yellow Sea and a shift in the wind may carry them onshore. These clouds usually cause light snow flurries as they encounter the hillsides.

The weather of December, January and February, under the influence of the northwest monsoon, generally remains clear and cold. The coldness of the outbreaks of polar air is accentuated by a dryness and gustiness that cause moisture to be evaporated from the skin; the "chill" temperatures therefore are frequently 20°F below actual temperatures (see Para. 3.3.3).

In January, sunrise is 0730-0800 and sunset 1730-1800, with the coldest temperatures in the cities between 0600 and 0800. During the night, a drainage wind brings cold, heavier air down the mountainsides and creates a well of cold air and a temperature inversion in the valleys. The smoke from charcoal fires and furnaces, when coupled with early morning vehicle traffic exhaust, often produces a mixture of smoke and haze that reduces visibility around the cities to 4-6 mi (6-10 km). This concentration may not be penetrated by sunlight until the sun is well up; air pollution in Seoul reaches its highest levels during these early morning periods.

The month of March is generally the beginning of the end of the cold winter season. Temperatures are about 9°F warmer than in February. While continental dry air from the Siberian high pressure area continues to dominate the weather over the Peninsula and generally fair weather conditions prevail, the Siberian high is rapidly weakening.

Incursions of moist air from the oceans surrounding the Peninsula become more frequent, increasing the level of cloudiness and precipitation by small amounts. In March the polar front has moved northward from its true

winter position and lies between Taiwan and the Philippines. About four to six times during this month, the Peninsula is affected by low pressure areas developing along the polar front somewhere between Taiwan and the area of Shanghai. The northeastward migration of these storms along the polar front brings short periods of warming southerly flow as far north as the Peninsula's southern coast. These storms produce increased cloudiness (even a thunderstorm or two) with short spasms of rain as far north as Taegu. After their passage, wintry weather returns.

3.2.2 Spring: April and May

In April, the Siberian high weakens and the polar front begins to move northward toward the Korean Peninsula with an increasing intrusion of warm moist air from the south. By the latter part of the month, the northerly winds from the high pressure area over Siberia are no longer dominant. The warmer air raises the temperature into the 60's (°F), and some southern cities such as Pusan and Chinhae have as much as six inches of rainfall.

Because the cold, heavier air that originated in Siberia is being displaced more and more frequently by tropical maritime air, the country is said to be under the influence of a "migratory high." This high is sometimes displaced by low pressure areas from the south, but it is also displaced, though less frequently, by low pressure areas originating over northern China or Mongolia.

The types of weather these lows bring to South Korea depend on their place of origin and the latitude in which they pass over the Peninsula (see Para. 4.3). Occasionally, a storm originating over the Mongolian desert can cause dry westerly winds over South Korea; these are known as "Yellow Winds" because they carry yellow dust picked up over the desert. An easterly wind of the foehn type (known on the Peninsula as "nopsae param," or "wind from the heights"), which descends the leeward slopes of the mountains, can be seen whenever a strong, easterly, onshore, surface wind is blowing. It is particularly apparent over the western and central sectors of South Korea when a low pressure area originating in northern China makes a spring passage over the Korean Peninsula. With the passage of this low, however, the migratory high may reestablish itself and bring cool, clear nights and devastating late frosts as far south as Kwangju. The average date of the last frost for more than a third of the country, including Seoul, is April 20.

In May and early June, the weather pattern changes in preparation for the onset of the rain-bringing southwest monsoon in late June. In May, the summer low pressure area that is developing over the continent of Asia is to the north of the Peninsula, rather than to the west as is the case later in the summer. Because of this, the predominant wind direction in May is westerly, rather than southwesterly, with little change in cloudiness and rainfall.

The amount of rainfall in South Korea in May is usually about the same as in April. The actual amount of rainfall during both months depends to a large extent on a region's location relative to adjoining mountains. Areas on the windward sides of mountains usually have an average of 8-12 days of cloudiness and/or rain, while areas on the leeward side have only 4-8 days. Investigations in the Naktong Basin indicate the annual rainfall in the mountains is 12% higher than in the valleys.

Since the pressure differences between the continent of Asia and the adjoining oceans are at a minimum in May and no large scale wind system predominates over the Korean Peninsula, purely local weather phenomena become more conspicuous. Radiation fog, advection fog and local winds are much more apparent at this time.

Sea and land breezes grow stronger with the warmer weather, and there are also local wind effects in the valleys. During the day, the enclosed heat of the valleys creates an updraft on the mountainsides, while at night the process reverses and sends cold air flowing down to lower levels. In places where valleys open to the sea, the combination of sea and valley breezes creates an up-valley funnelling effect during the day, while at night the mountain breeze combines with the land breeze to produce a vigorous downdraft to the sea. At Chinhae, winds strengthened by this effect have been measured at 35 kt with gusts of more than 58 kt.

3.2.3 Summer: June to Mid-September

June marks the beginning of the summer, or southwest monsoon. June surface winds across the Peninsula are variable, but predominantly from the south toward a low pressure center over Manchuria. By July, this onshore flow of air is well established and persists until the latter part of September (Figure 3-2). It should be noted here that a knowledge of both the air masses affecting the region and the movement of the polar front is basic to an understanding of summer's weather changes.

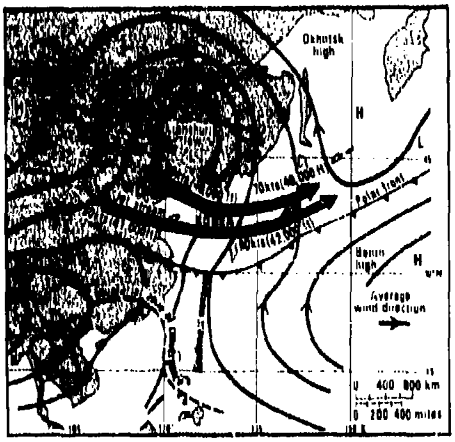


Figure 3-2. June mean pressure and wind systems (from 1st Weather Wing, USAF).

The polar front is the boundary zone between continental air masses from Asia and the warm moist air from the tropical oceans. This boundary gradually advances northward with the coming of summer. In February, it is as far south as the northern Philippines. By June, its average location runs from Shanghai east to southern Japan, and then northeast, parallel to the southern coast of Japan. The front is a buffer zone between the cooler northern air mass and the warm southern air. The light but persistent rains associated with the front, known as "Bai-U" or "plum rains" in Japan, affect southern Japan by the end of May.

The coming of sufficient rainfall to support South Korean agricultural needs is always a chance affair; in about one year out of five, the rains come too late. Such a lack of rainfall occurs when a high pressure cell to the north of Japan is unusually strong. This so-called Okhotsk high fends off the polar front and inhibits its progress toward the Peninsula. The Okhotsk high is quite distinct from the Bonin high pressure area which forms further south and dominates the western Pacific. In those years when the Okhotsk high is strongly developed, the arrival of the rains is delayed and the area suffers from drought.

Generally, however, the amount of rainfall in June, and particularly in the latter part of June, increases very substantially above that of the winter and spring months. Sunchon, near the southern coast, has an average June rainfall of 9.5 inches, Pusan 8 inches, and Sogwipo, on the southern shores of Cheju Island, 10.6 inches. Elsewhere the amounts are generally 4-6 inches. Temperatures also rise rapidly, with daily maximums of about 82°F. The highest temperature ever recorded in June was 102°F at Tongduchon, north of Seoul, but several locations have recorded 99°F and Seoul's maximum is 100°F. With the onset of the rains and the increase in temperature, the humidity also increases; relative humidity averages 70-80% for the month of June and is greatest in the west and southwest. The days are long, with sunrise shortly after 0500, sunset just before 2000, and twilight lasting an additional half hour (see Para. 3.3.12).

In July, two main weather changes affect the region. The Bonin high pressure cell expands westward into the East China Sea, while a large continental low caused by landmass heating settles over northern China. This gives the Korean Peninsula high pressure to the south and low pressure to the north and creates an airflow that brings warm moist tropical air from the south. The polar front runs from Peking to Cheju Island and then across to central Japan, producing widespread cloudiness. The front is not stable and develops waves; these generate lows that intensify the cloudiness and rain.

Three or four of these lows push across the Peninsula during July, and often they stall in the Korea Strait against the mountains of western Honshu. These "hesitant" lows bring the wettest month of the year. In many

years there may be a total of as much as 17 inches of rainfall, with rain to be expected on about half the days of the month. (Seoul once had 53 inches of rain in July.) The maximum rainfall in 24 hours in July was 12 inches. The passage of one of the lows is frequently followed by a day or two of clear weather, with some thunderstorm activity developing in the afternoon.

June has the longest day and July is the month of the summer monsoon, but in many respects August is the most typical summer month. By August the polar front has passed over South Korea and has a mean position over North Korea. South Korea then experiences extremely unstable tropical air south of the front; when there is no cloud cover, temperatures rise into the 90's (°F) with equally high relative humidities.

In September the average temperatures decrease to the high 70's (°F), although the extreme maxima may still reach the mid-90's (°F), and the average rainfall is less than during August. The polar front, which made relatively slow progress in its northward movement during June and July, moves very rapidly southward again in September. The front's southward movement can be traced by the accompanying wide band of rain. During this southward frontal movement, weather along the east coast of South Korea becomes very turbulent with exceptionally heavy downpours. By the end of September, the polar front is south of Okinawa; the overall result is the replacement of the southerly flow of warm, moist, tropical air of the summer monsoon by a cooler, drier flow from the north.

3.2.4 Fall: Late September and October

As the Asian land mass cools, the Siberian high begins to form in September and becomes more noticeable in October. Most of the Western Pacific experiences the effect of this large scale change when cooler air masses break away from the Siberian high and are carried southward. In the Korean area this change in the weather often occurs about the time of "Chubun," the autumnal equinox.

By October, the southward surges of colder air become stronger and more frequent. The mean position of the polar front, so recently over the Korean Peninsula, now extends from near Hong Kong to the south of Taiwan. October is a very pleasant month characterized by sunny days with maximum temperatures in the mid 60's (°F) and cool nights with temperatures falling into the 40's (°F).

By mid-November, the winter weather pattern is established. The polar front is now far to the south and freezing temperatures and some snow can be expected. The second week of November is considered the beginning of winter. The average date of the first snow for most of the country is 20 November, and temperatures fall below freezing 10 or more days in the month.

3.2.5 Seasonal Summary

The various weather phenomena described in the preceding paragraphs are summarized by month and season of occurrence in Table 3-2.

Table 3-2. Climatic calendar for South Korea (source: Det. 18, 20th Weather Squadron, 1st Weather Wing, USAF).

<table>
<tr><td>MAR.</td><td>APR.</td><td>MAY</td><td>JUNE</td><td>JULY</td><td>AUG.</td><td>SEP.</td><td>OCT.</td><td>NOV.</td><td>DEC.</td><td>JAN.</td><td>FEB</td></tr>
<tr><td colspan="3">SPRING</td><td colspan="3">SUMMER</td><td colspan="3">AUTUMN</td><td colspan="3">WINTER</td></tr>
<tr><td>North-west Monsoon</td><td colspan="2">Transition period</td><td colspan="4">South-west Monsoon[7]</td><td>Transition period</td><td colspan="4">North-west Monsoon</td></tr>
<tr><td colspan="2">Yellow wind[2]</td><td rowspan="2">Late frost[3]</td><td colspan="2">Rainy season</td><td rowspan="2">Bonin High predominates</td><td rowspan="2">24 hour precip exceeds 12 inches owing to typhoon</td><td colspan="3" rowspan="2">Under influence of migratory high, elongated east-west mean track along 38° N.[10]</td><td colspan="2" rowspan="2">Heavy snow may be expected along Taebaek Mts with strong north to south pressure gradient (high to north)</td></tr>
<tr><td>Foehn[1]</td><td></td><td>Polar front South of R.O.K.</td><td>Heavy Rain[8]</td></tr>
<tr><td colspan="3">Blocking due to slow-moving Mongolian high results in cut-off low over Yellow Sea.</td><td>Pressure higher to east.</td><td colspan="3">High pressure area to south; low to north.</td><td></td><td colspan="4">High pressure area to west; low to east.</td></tr>
<tr><td colspan="3">Korea under influence of migratory high[4]</td><td colspan="3">Typhoons may affect R.O.K.[9]</td><td colspan="4">Exceptionally good visibility over long distance within migratory high area.[11]</td><td colspan="2">'3 cold and 4 warm day cycle' prevails over Korea.</td></tr>
<tr><td>Gust winds[5]
Taiwan lows</td><td colspan="2">Frontal thunderstorms duration 1–2 hrs. up to twice per month.[6]</td><td colspan="3">Airmass thunderstorms, 5–10 km. diameter; 2–5 per month.</td><td colspan="2">Frontal thunderstorms, 0–2/month</td><td colspan="2">Shanghai low may develop and affect R.O.K.</td><td colspan="2">Taiwan lows frequently affect R.O.K.</td></tr>
<tr><td></td><td colspan="4">Sea fog, most frequent in July over Inchon area. Frontal and radiation fog may occur occasionally.</td><td colspan="5">Radiation and frontal fogs occur frequently, however duration is short. Radiation fog seen inland.</td><td colspan="2">Siberian airmass dominates Korea.</td></tr>
</table>

[1] North China low passing over North Korea causes foehn (hot, dry south to easterly flow) over west and central sectors of R.O.K.
[2] Mongolian low passing over southern Manchuria causes yellow winds (strong, dry west wind carrying yellow dust).
[3] Late frost may occur when migratory high predominates over R.O.K.
[4] Mean track of migratory high is along 33° N.
[5] Low over Shantung Peninsula may cause gusty winds over R.O.K.
[6] Intense frontal thunderstorms in May signal approach of rainy season.
[7] Cool summer and drought if South-west Monsoon weak and Okhotsk High intense.
[8] Heavy rain-latter part of rainy season.
[9] Hot and humid with maritime tropical air intrusion. None or as many as two tropical storms or typhoons from end of June through September may affect R.O.K.; least likely in August owing to Bonin High.
[10] Migratory highs move at about 20 knots, speed up with northward movement and vice versa.
[11] Often precedes bad weather.

3.3 METEOROLOGICAL CLIMATIC DATA

3.3.1 Temperature and Humidity

The temperature regime on the Korean Peninsula greatly influences military operations: personnel movement, vehicle operations and aircraft operations are particularly subject to temperature effects. Mean monthly temperatures for January (winter) and July (summer) are shown in Figure 3-3.

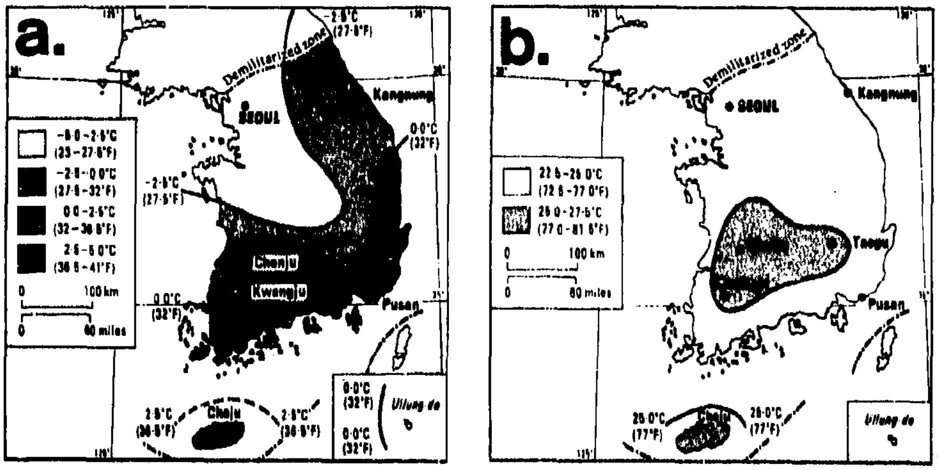


Figure 3-3. Mean monthly temperatures in South Korea for (a) January and (b) July (from Bartz, 1971).

In the winter, mean daily maximum temperatures across the Peninsula are only moderately cold with readings in the range 30° to 45°F (-1° to 7°C). These relatively warm maximum temperatures occur during those periods when the cold, winter monsoonal flow tracks over the Yellow Sea or Sea of Japan and fairly rapid warming in the lower levels occurs from contact with the relatively warm sea.

Mean daily minimum temperatures, however, can be extremely cold, especially during December to February when early morning readings fall to the low 20's (°F). Very low temperatures have been recorded at low elevations during particularly severe incursions of polar air, and the extremes are appreciably colder in the mountain areas. The lowest temperature ever recorded at a non-mountainous station is -16°F at Osan; Seoul once recorded -7°F. The lowest temperature ever recorded in South Korea as a whole was -23.1°F.

In summer, the monsoon circulation has a long trajectory over tropical waters and this is reflected in the season's high temperatures and humidities. The increase in temperature is especially evident in July and August when mean daily maximums are in the middle or upper 80's (°F) with mean daily minimums in the low 70's (°F) at most places.

Humidity is generally high throughout the year as a result of the surrounding water mass, and regional variations are generally small. Mean relative humidities are usually highest in the early morning, 60-95%. Highest values occur in summer or early fall with a minimum in winter. Daily minimums usually occur during early afternoon, 50-85%. At higher elevations, humidity can drop to 35%. Although diurnal changes vary from place to place, they are generally greatest in the interior.

A variety of temperature conditions are summarized in Figures 3-4 through 3-8. Average monthly humidities for selected reporting stations are listed in Table 3-3.

Table 3-3. Monthly and annual averages (in %) of atmospheric relative humidity for selected South Korean stations.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kangnung	49	57	61	59	63	75	80	81	76	66	60	53	65
Seoul	64	64	64	63	66	73	81	78	73	68	68	66	69
Inchon	66	67	69	70	74	80	86	82	75	69	68	67	73
Ullung-do	69	69	67	66	69	79	85	83	76	67	66	65	72
Chupungnyong	62	62	62	60	63	71	78	78	76	67	66	65	72
Pohang	53	57	62	65	69	77	83	81	78	69	66	57	68
Taegu	57	58	58	61	64	69	76	75	76	69	67	62	66
Chonju	73	72	71	70	72	76	80	80	79	76	75	75	75
Ulsan	56	59	65	71	76	81	84	82	80	73	68	60	71
Kwangju	74	72	71	72	74	77	82	80	80	76	75	75	76
Pusan	49	52	59	66	71	80	85	80	74	64	59	58	66
Mokpo	69	69	69	71	75	80	84	80	76	70	69	68	78
Yosu	55	57	62	67	72	79	87	80	74	64	60	57	68
Cheju	67	68	68	72	75	79	81	80	79	79	68	67	78

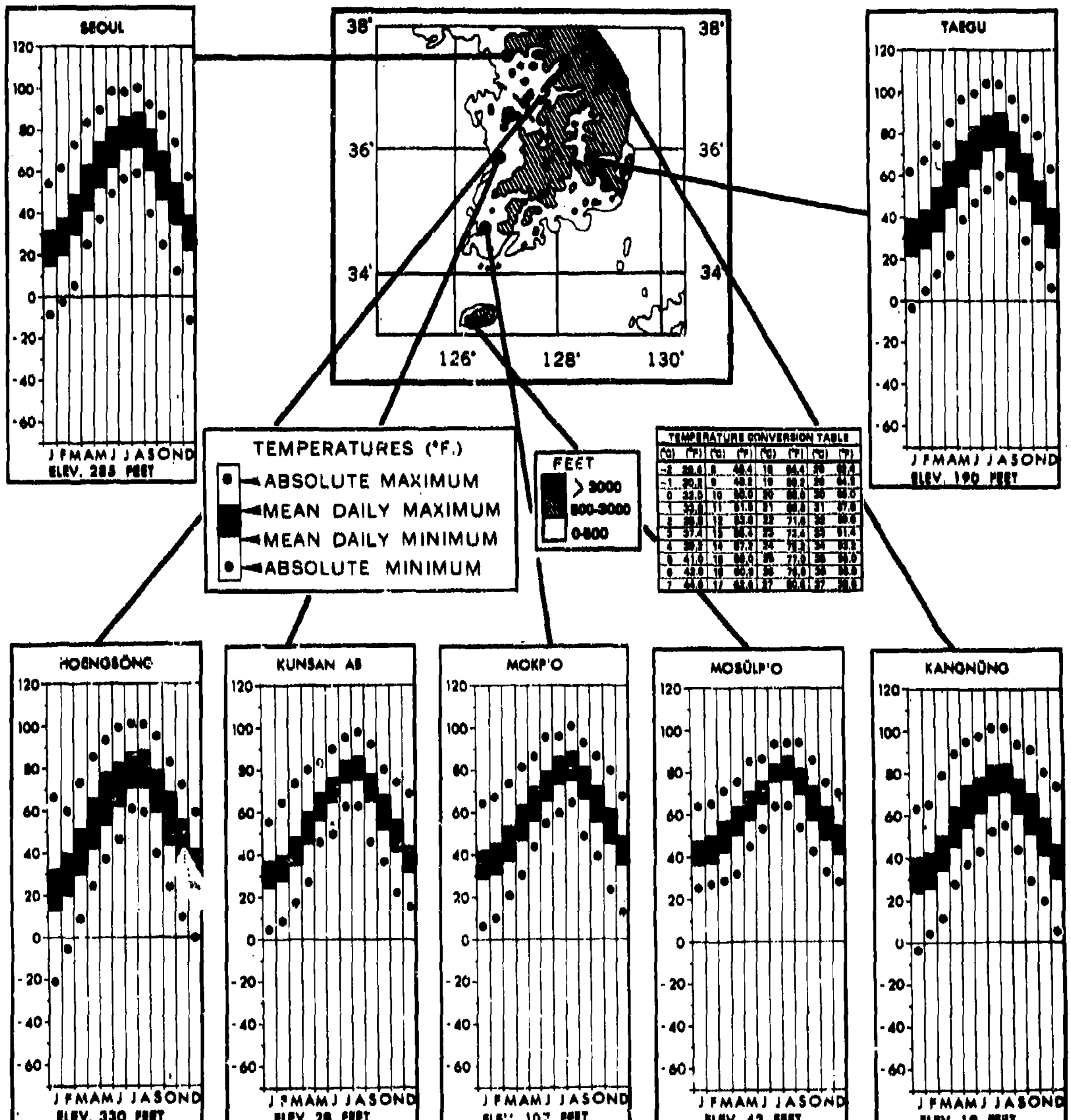
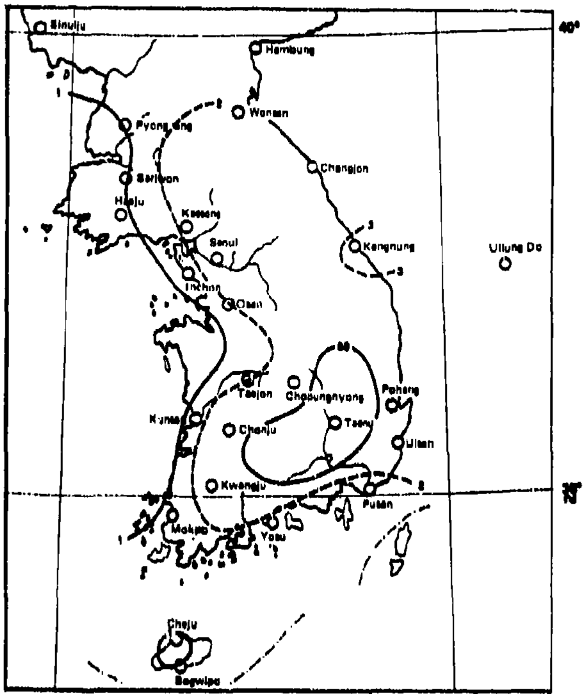
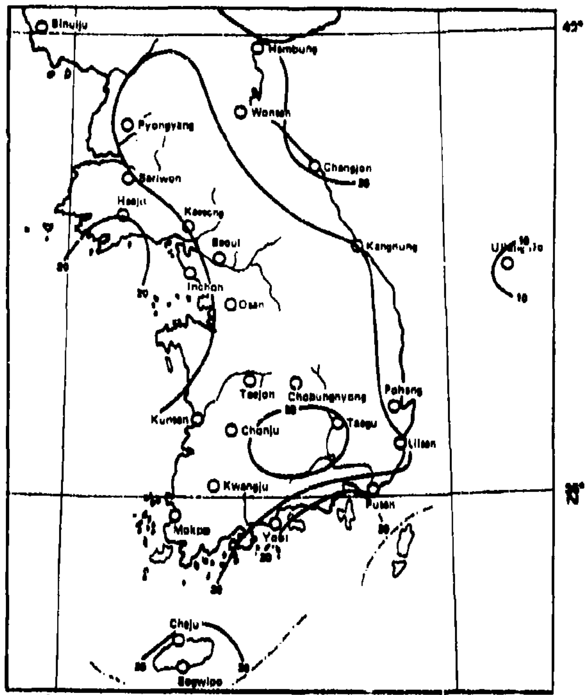


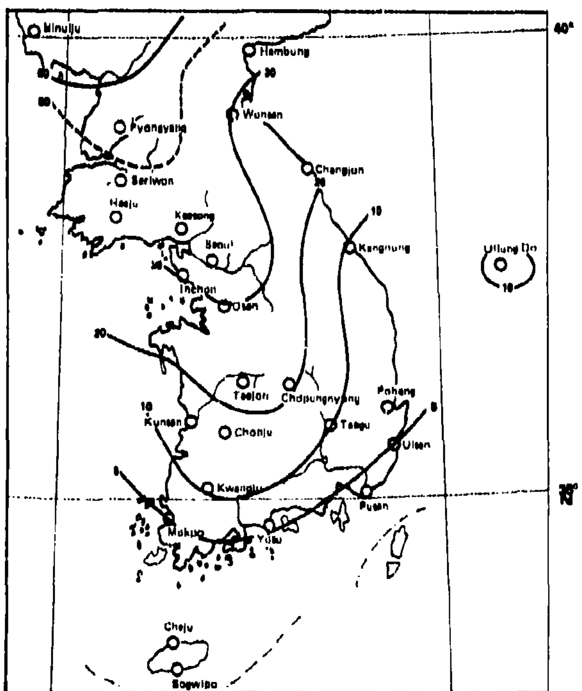
Figure 3-4. Temperatures (°F) for selected South Korean locations.



NUMBER OF DAYS WITH MAXIMUM TEMPERATURE MORE THAN 35°C (95.0°F)



NUMBER OF DAYS WITH MAXIMUM TEMPERATURE MORE THAN 30°C (86.0°F)



NUMBER OF DAYS WITH MAXIMUM TEMPERATURE LESS THAN 0°C (32.0°F)

Figure 3-5. Maximum temperature data (°F) for South Korea (from Climatic Atlas of Korea, 1962).

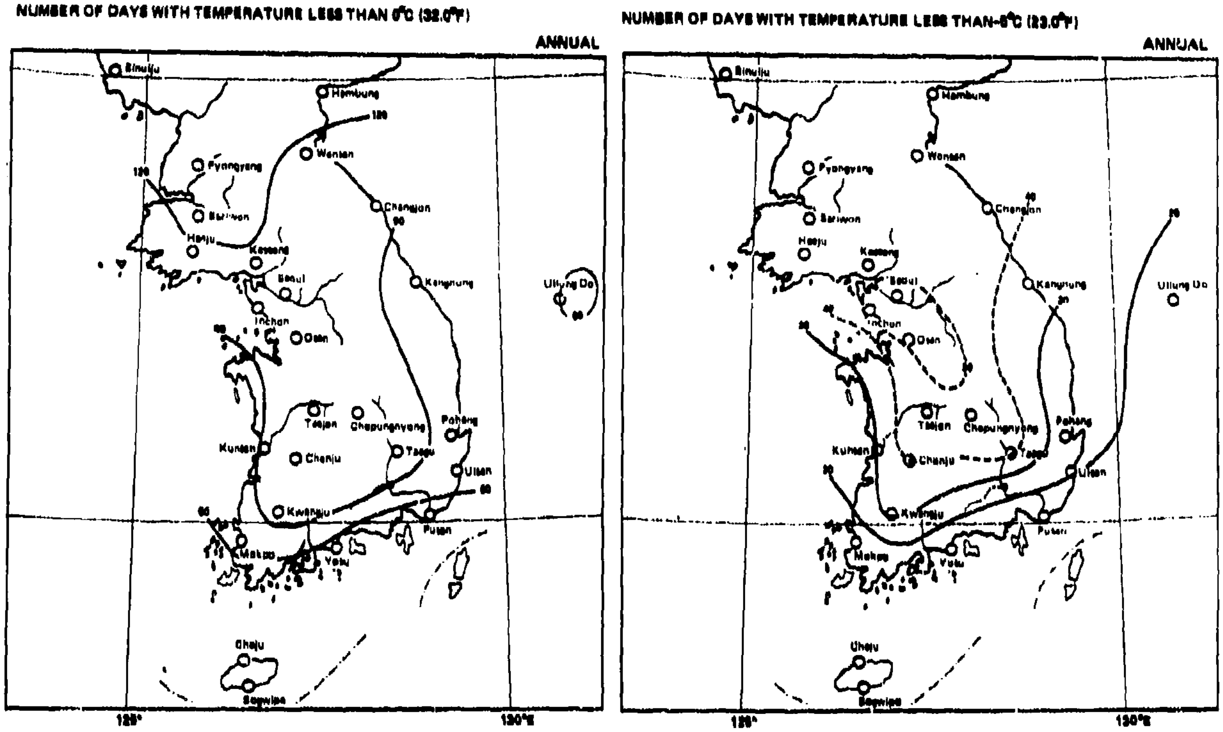


Figure 3-6. Minimum temperature data (°F) for South Korea (from Climatic Atlas of Korea, 1962).

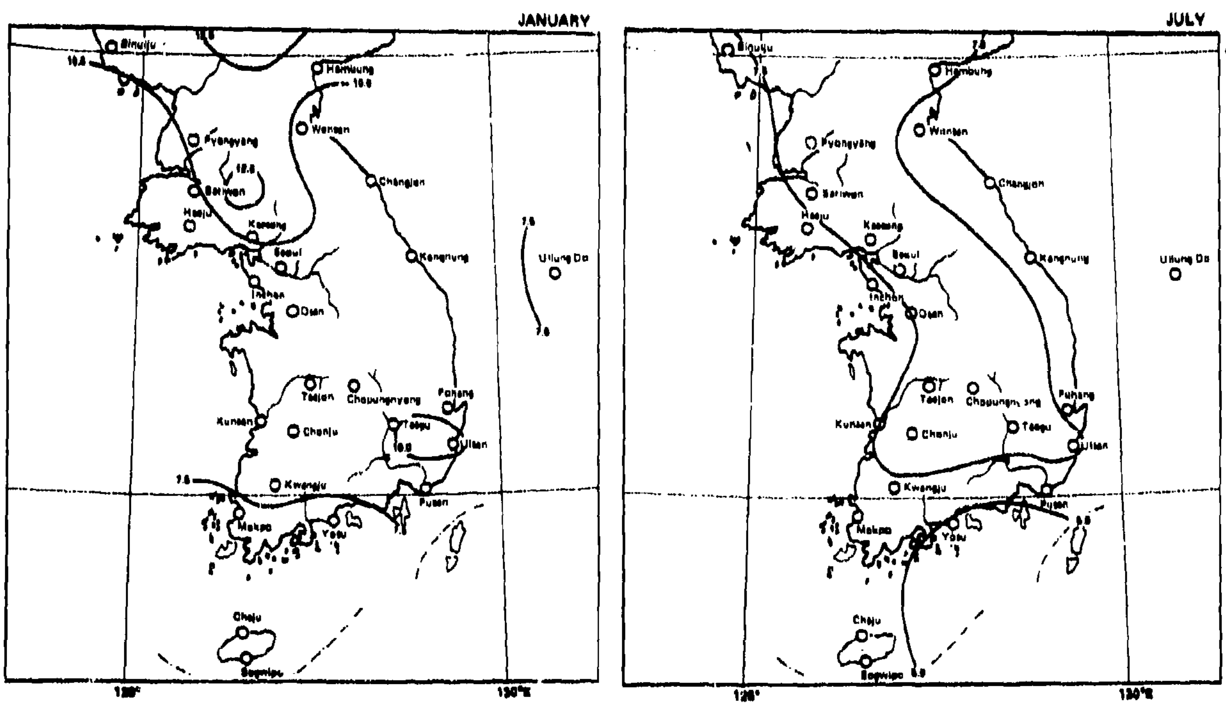


Figure 3-7. Mean temperature ranges (°F) for South Korea (from Climatic Atlas of Korea, 1962).

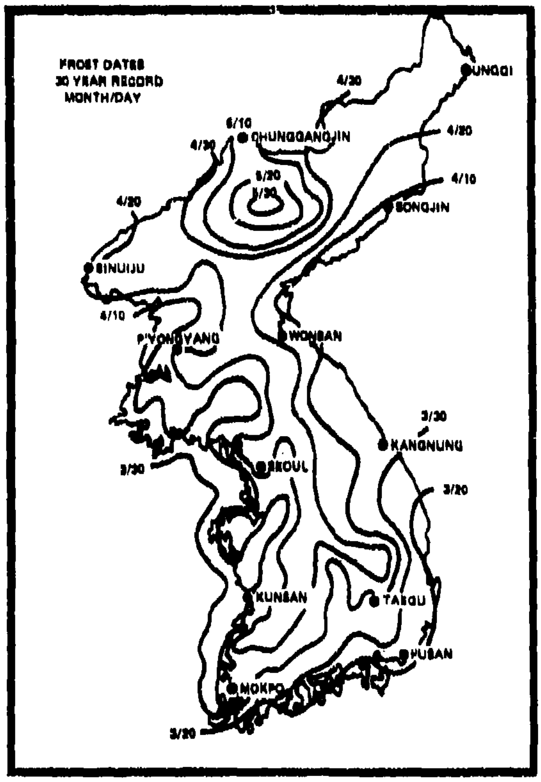


Figure 3-8. Mean date of last frost (from 1st Weather Wing, USAF).

3.3.2 Precipitation

Precipitation across the Korean Peninsula shows large seasonal and regional variations, with the latter due mostly to the mountainous terrain. Rainfall is generally associated with the summer monsoon and occurs mainly during June through August. The greatest rainfall occurs along the southern slopes of Cheju-do where the incoming monsoonal air mass makes landfall and rises across Mt. Halla. The small port of Sogwipo on the island's south coast has an average annual rainfall of 71.5 inches. The total annual precipitation in South Korea generally ranges from 40 to 55 inches. An area around Taegu encircled by the Sobaek and Taebaek mountain ranges receives an annual total of about 30 inches. Annual average precipitation levels are shown in Figure 3-9.

Climatological rainfall data should be used with caution in forecasting, because wide variations can occur in the annual amounts of rainfall. Extreme deviations from the mean (exceeding 40%) can occur and a series of three successive dry years have occurred during the past 40 years. Seoul, with average annual rainfall of 49.6 inches, has recorded an annual high of 83.3

inches and a low of 24.7 inches. The record high for a mainland station is 92.7 inches (Hadong, 1936) and the record low is 16.8 inches (Pohang, 1914).*

Daily precipitation of 0.4 inches or more occurs on approximately 45 days per year in the southern part of the Peninsula. In the drier winter period this amount is generally observed on one to two days each month; the frequency gradually increases to a maximum of five to ten days per month in summer. About 66% of the average year's rainfall is concentrated in the four-month rainy season, June through September. Only 16% occurs in spring (April and May) and the remaining 18% is spread over the other six months (October through March).

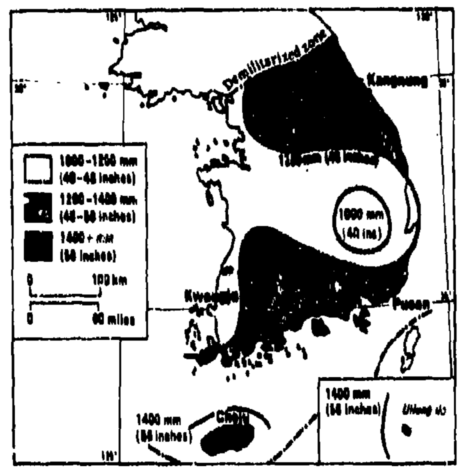


Figure 3-9. Annual average precipitation (from Bartz, 1971).

In the rainy summer period, rainfall of varying intensity can be expected on an average of 10 to 20 days per month, decreasing to an average of nearer five days per month during the rest of the year. Exceptions to this trend are the islands located to the south and southwestern tip of the Peninsula, where about 10 to 15 rainy days are experienced in most months of the year. Mean annual precipitation at selected reporting stations is shown in Figure 3-10.

Typhoons are responsible for the heaviest rainfall, and this explains the wide variation in annual rainfall totals that produce flood conditions one year and drought conditions in other years (see Para. 3.3.7, Typhoons). Of all heavy rainfall situations, 90% fall into one of three categories. One is the typhoon, in which the heaviest rain usually occurs ahead of the typhoon passage. The other two involve the polar front with and without wave development (Figures 3-11, 3-12), and the migration of low pressure systems across the Peninsula (Figures 3-13, 3-14). Table 3-4 lists temperatures and rainfalls at South Korea's major cities.

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*Modern data. Old records show annual precipitation of 101.8 inches at Seoul in 1823.

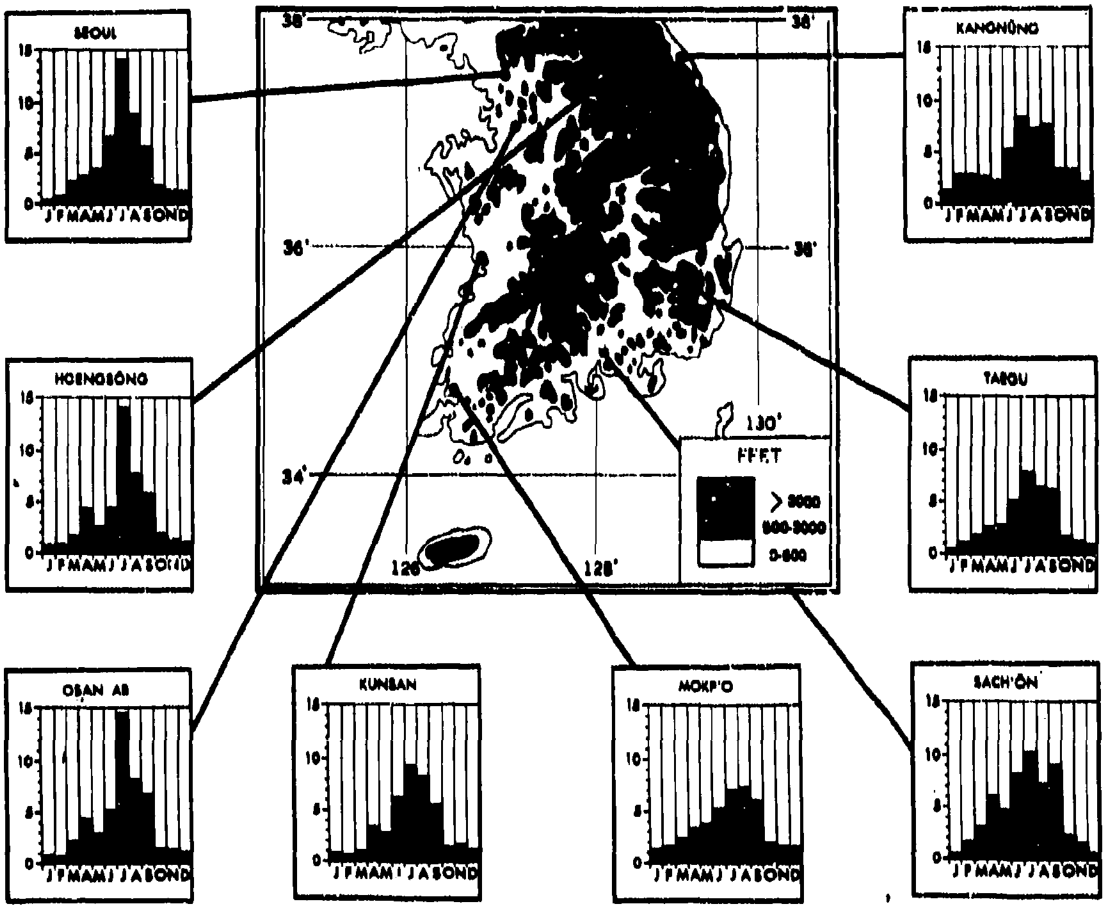


Figure 3-10. Mean precipitation in inches for selected South Korean locations.

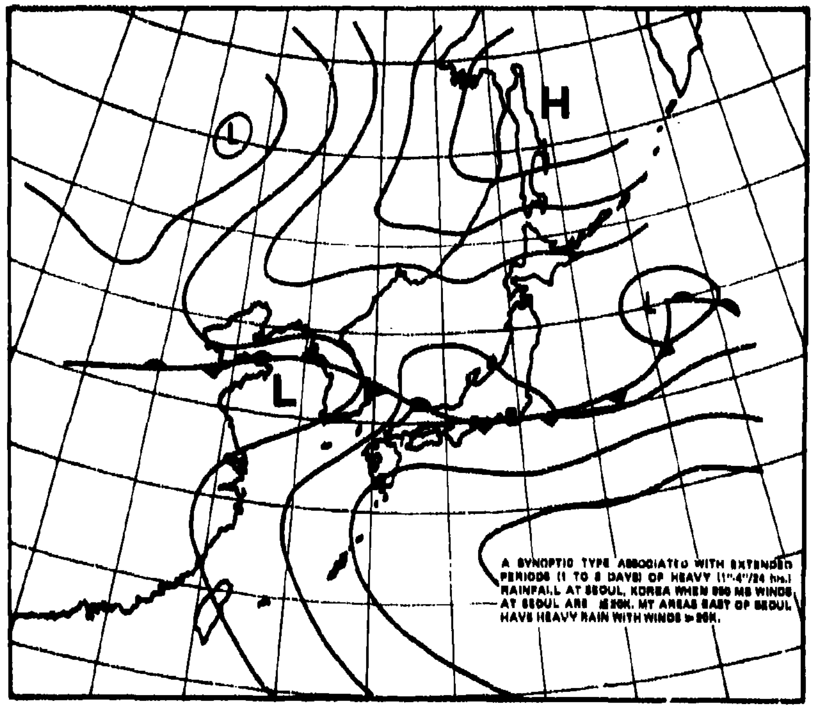


Figure 3-11. Flood forecasting for Korea May-Sep — frontal passage without wave development (from 1st Weather Wing, USAF).

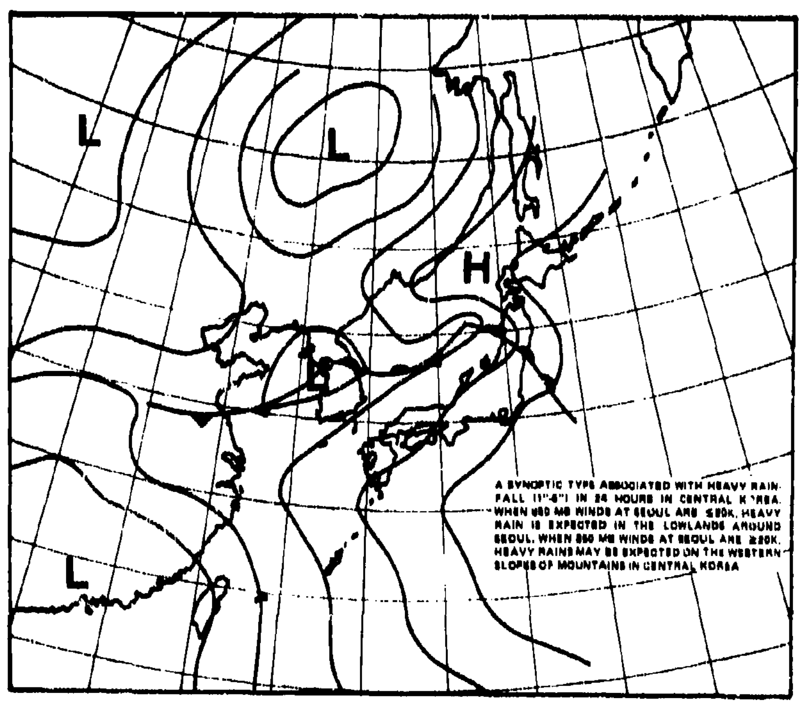


Figure 3-12. Flood forecasting for Korea May-Sep — frontal passage with wave development (from 1st Weather Wing, USAF).

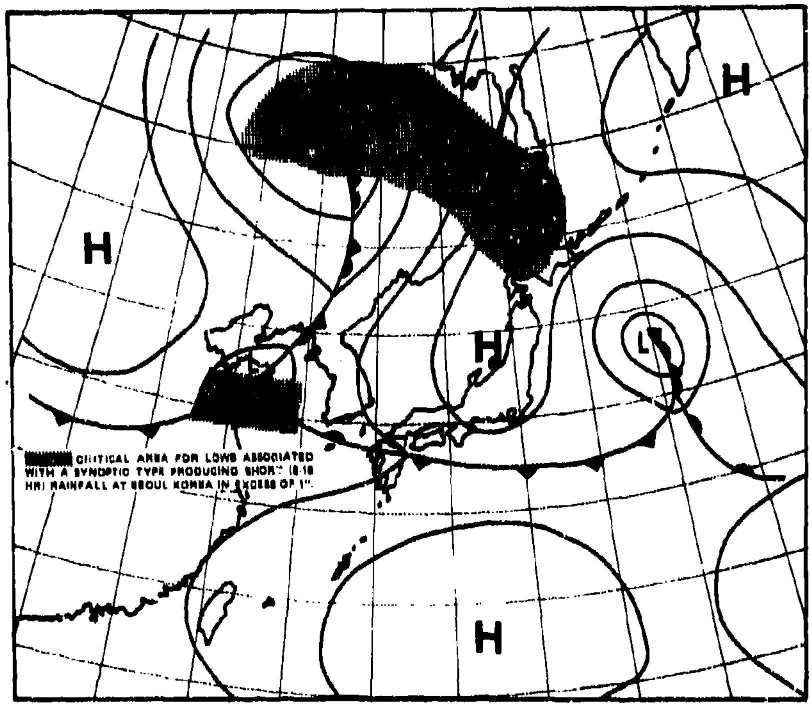


Figure 3-13. Flood forecasting for Korea May-Sep — migration of low pressure system (from 1st Weather Wing, USAF).

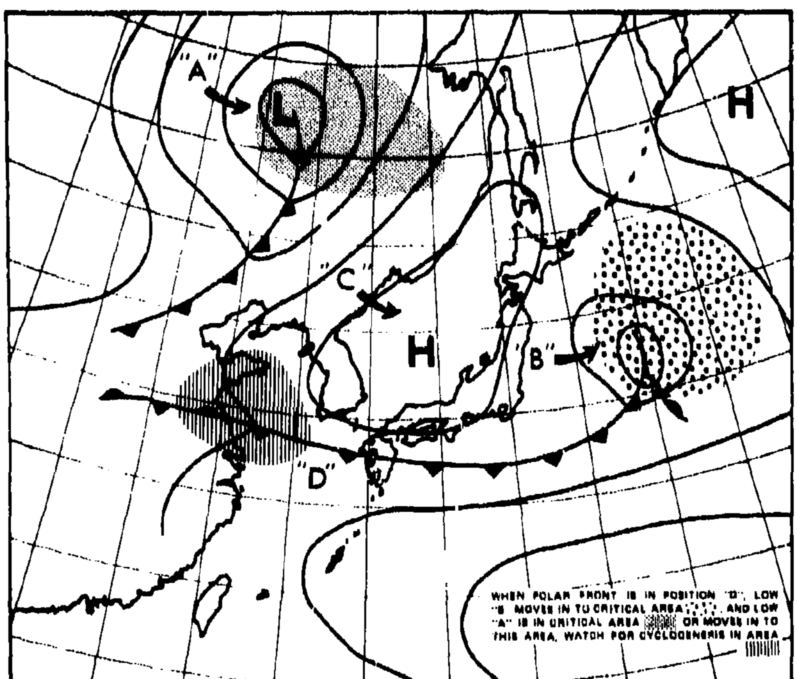


Figure 3-14. Flood forecasting for Korea Sep-May -- migration of low pressure system following cyclogenesis in the Yellow Sea (from 1st Weather Wing, USAF).

Table 3-4. Monthly temperatures and mean monthly/annual rainfall for major South Korean cities (temperatures °F; rainfall in inches).

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
SEOUL													
Record maximum	60	60	65	83	92	99	100	101	91	82	70	57	
Average maximum	32	38	48	62	72	78	84	86	77	67	52	38	
Average minimum	16	21	31	43	53	62	71	72	60	46	35	23	
Record minimum	-7	-1	11	25	39	50	57	60	42	27	13	-5	
Average rainfall	1	1	2	4	2	7	14	9	6	2	1	1	49.6
KUNSAN													
Record maximum	61	66	73	84	90	95	97	101	95	84	81	67	
Average maximum	36	39	47	59	69	75	83	85	77	67	55	43	
Average minimum	24	27	35	45	55	64	73	74	64	51	41	31	
Record minimum	-2	5	8	23	33	44	51	53	40	22	10	0	
Average rainfall	2	1	2	4	4	5	10	6	6	2	2	2	46.3
TAEGU													
Record maximum	61	67	78	87	99	101	103	103	95	86	78	70	
Average maximum	38	42	52	65	75	82	87	88	79	69	56	43	
Average minimum	21	24	32	43	53	62	71	72	61	47	36	25	
Record minimum	-4	2	12	21	35	46	52	57	43	28	16	4	
Average rainfall	1	1	1	3	3	5	8	7	5	2	1	1	38.2
KANGNUNG													
Record maximum	62	64	78	88	94	96	101	100	92	89	79	73	
Average maximum	36	41	49	60	71	75	81	83	75	66	56	46	
Average minimum	22	26	33	43	53	60	68	70	58	47	38	30	
Record minimum	-4	4	11	26	36	43	52	54	43	30	18	5	
Average rainfall	1	3	3	3	3	5	8	8	8	3	3	2	50.4
PUSAN													
Record maximum	65	64	73	78	92	92	95	97	90	81	75	69	
Average maximum	44	48	54	63	71	75	81	84	78	70	60	50	
Average minimum	28	32	38	47	56	63	71	73	65	54	42	33	
Record minimum	7	11	17	29	42	49	57	55	48	33	25	10	
Average rainfall	1	3	3	5	5	6	9	7	7	3	3	1	52.1

(Source: Air Weather Service Climatic Briefs, 20th Weather Squadron, U.S. Air Force)

Because winter is the dry period in this region, not much of the general annual precipitation falls as snow. The maximum depth of snow occurs on the exposed mountainous island of Ullung-do off the east coast (37°29'N, 130°54'E), where seven to eight feet generally fall during the year and an accumulation of 9.5 inches was once recorded in one day (31 Jan 1962). On the mainland, heavy accumulations of almost seven feet occur in the Taebaek Mountains during winter storms, but the maximum depth ever recorded in any city was 51 inches at Kangnung on 2 Jan 1923. Kangnung averages about eight days of snow per month in the winter, while Taegu averages four and Seoul and Pusan each two (Figure 3-15). Seoul has never had more than 17 inches of snow on the ground and the maximum for any 24 hours is about 12 inches (a phenomenon which occurs about once every 40 years). The customary "heavy" snowfall is about four inches.

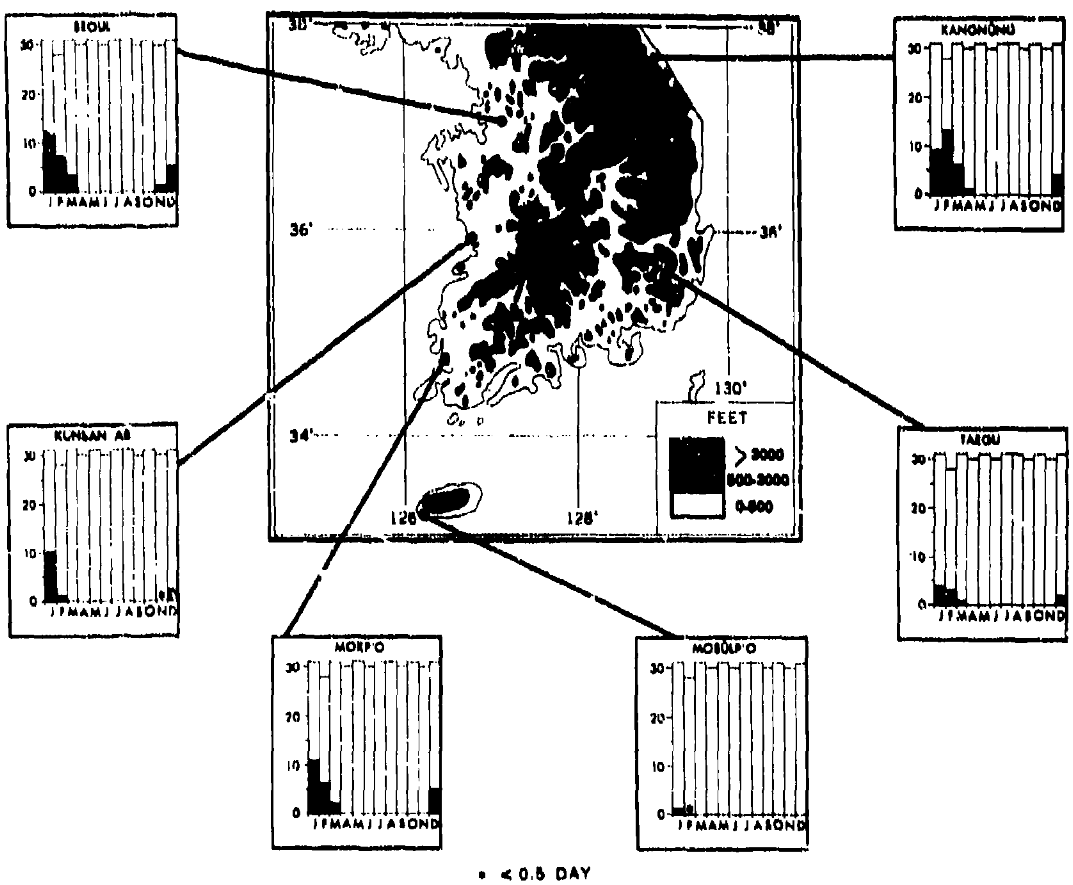


Figure 3-15. Mean number of days with snow cover.

Snow can be expected to occur beginning about the middle of November continuing intermittently until approximately the end of February. Snow generally will be on the ground for a mean period of 12 days in January and seven in February, but falls usually are slight. Except in cases of isolated massive winter storms, transportation generally is not significantly affected by snow or ice.

3.3.3 Surface Winds and Windchill

Surface winds are primarily determined by the monsoonal system and the subsequent modifying effects of topography. Figure 3-16 shows wind roses for the four quarters of the year. The monsoon influence is evident from the wind's generally southerly component in summer and northerly component in winter The effect of topography is dramatically demonstrated by the great diversity of winds at the various locations; predictably, locations well protected by the surrounding topography have a higher percentage of light and variable winds. The summer monsoon is relatively weak in wind strength and the winter monsoon is the stronger of the two regimes. Calm conditions during the fall and winter are generally only found inland where the terrain provides protection.

Gale force winds are infrequent, generally occurring on fewer than 10 days annually and then usually in winter, though there is little evidence to distinguish a seasonal pattern. Since strong winds are associated with advancing typhoons, the summer period of maximum typhoon threat will produce gale force winds on those occasions when typhoons affect the Peninsula (an average of once or twice per year). The greatest wind velocities have occurred over Cheju-do Island (see Para. 3.3.4) where winds of 75-80 kt have been recorded. The strongest typhoon winds ever experienced in South Korea were those associated with Typhoon Sarah (see Para. 3.3.7).

Valley/mountain winds and land/sea breezes are important features of the surface wind pattern. Valley and mountain winds are naturally prominent in the mountainous interior where daytime valley winds blow as warmed surface air rises up the valley; during the night the mountain wind blows as cool air sinks down the mountain slopes. Land and sea breezes are usually superimposed on the monsoonal flow to give a hybrid wind condition, whereas the valley and mountain winds will generally be more distinct and protected from the general circulation by surrounding topography. Sea breezes in summer will usually commence around mid-morning, blowing from sea to land, and subside around sunset to be replaced by a land breeze that generally subsides around sunrise.

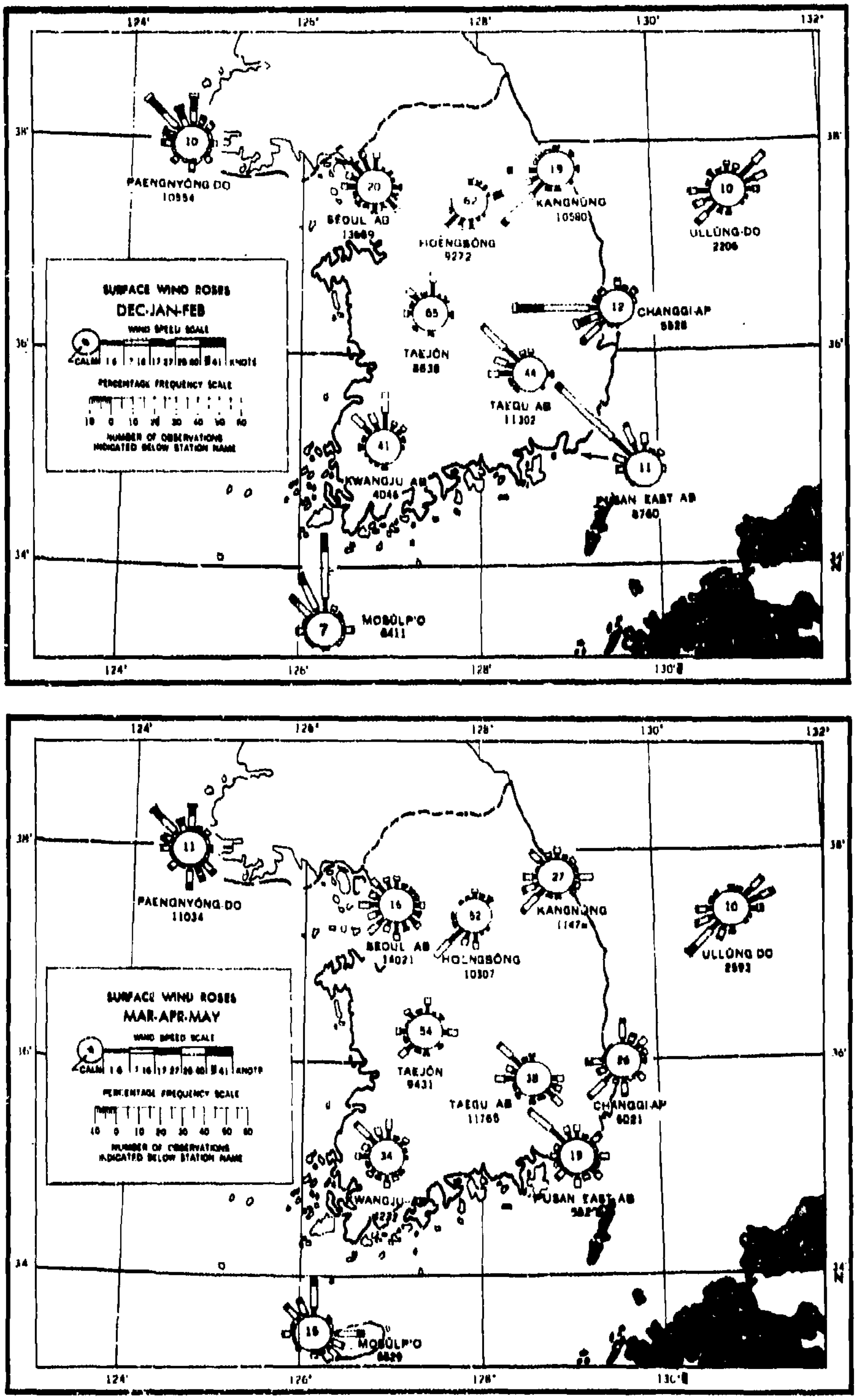
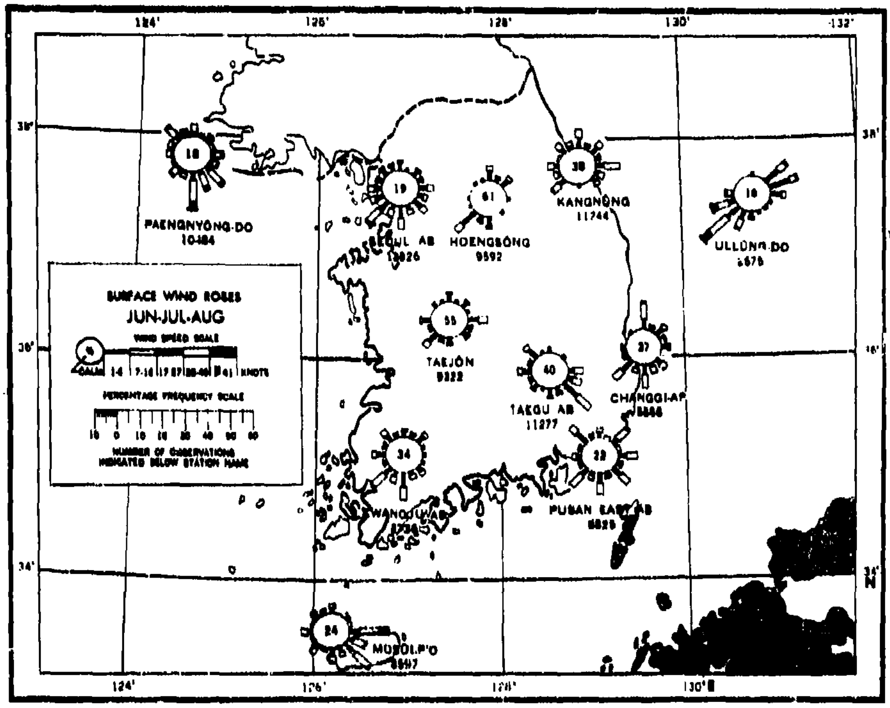


Figure 3-16. Wind roses for South Korea: winter, Dec-Jan-Feb; spring, Mar-Apr-May; summer, Jun-Jul-Aug; fall, Sep-Oct-Nov (from Climatic Atlas of Korea, 1962).



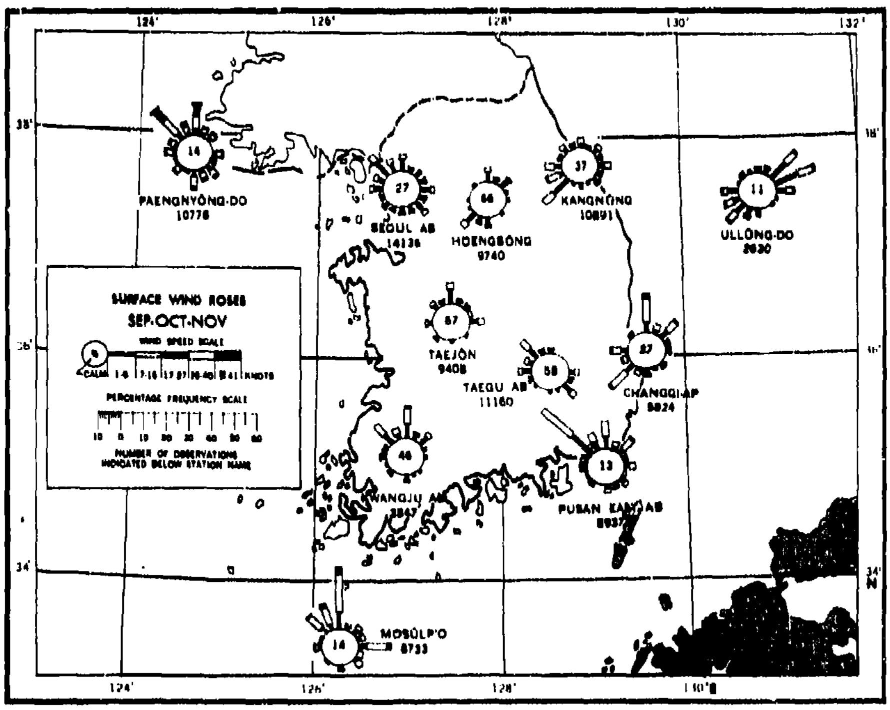
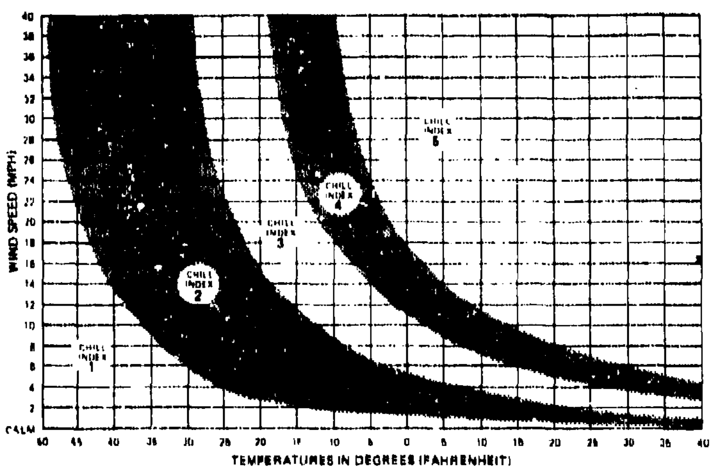


Figure 3-16 continued.

Because of the Peninsula's mountainous nature, many winds are locally produced; the three major wind types are the foehn, fall and jet effect (see Para. 3.2.2). Foehn winds are most frequent during the afternoon and evening hours of early spring and late fall, although they may occur in any month with the possible exception of July and August. The fall winds result from the movement of air down mountain slopes, but differ from foehn winds in that the air is initially cold enough to remain relatively cold despite warming during the descent. Jet effect winds are actually increases in wind speeds caused by the channelling of air through mountain passes or canyons. (Note: Very little information is available concerning local occurrences of fall and jet effect winds.)

Wind speeds can combine with temperatures to have a pronounced effect on human comfort through the phenomenon known as "windchill." For example, the body will feel much colder at a temperature of 45°F with a wind speed of 35 kt than at a temperature of 25°F with calm winds. Figure 3-17 charts windchill index conditions 1-5 in order of increasing severity. Conditions 4 and 5 are generally rare in South Korea. Condition 3 is usually the most severe case observed, mostly in January and in the northern and central interior. Areas in the far south and near the southern coast rarely experience anything more severe than condition 2.



1. COMFORTABLE. WITH NORMAL PRECAUTIONS
2. VERY COLD. TRAVEL BECOMES UNCOMFORTABLE ON OVERCAST DAYS
3. BITTERLY COLD. TRAVEL BECOMES UNCOMFORTABLE EVEN ON CLEAR SUNNY DAYS.
4. FREEZING BEGINS. TRAVEL AND LIFE IN TEMPORARY SHELTER BECOMES DISAGREEABLE.
5. SURVIVAL EFFORTS ARE REQUIRED. EXPOSED FLESH WILL FREEZE IN LESS THAN ONE MINUTE.

Figure 3-17. Temperature/windchill index (from NWSED, NAS, Patuxent River, MD).

Diurnal surface winds are also of interest, particularly along the east coast. Diurnal variations are especially prominent during the presence of a high pressure cell or ridge over the Yellow Sea; when these appear in winter, the monsoon flow will increase in mid-afternoon and late evening hours to as high as 35 kt from a westerly direction. A minimum will occur in mid-morning.

Ordinarily a tight gradient indicating strong northwest or westerly winds over South Korea will cause extremely gusty and variable winds from west to southwesterly along the east coast. If the gradient indicates light westerlies, the direction and speed will be constant. Westerly winds should be forecast with caution, because usually the actual wind is either much more or much less than the gradient wind indicates.

3.3.4 Upper Air Winds and the Jet Stream

The Korean Peninsula lies within a belt of prevailing westerly upper air winds. At around 30,000 ft (9144 m), strong westerly winds occur as part of the global high level wind system in a band of strong winds known as the jet stream. In January the axis of the jet stream blows west to east across the southern part of South Korea at average speeds of 195 kt and elevations of 35,000 to 40,000 ft (10,600-12,200 m) (Figure 3-18). The location of the northern edge of this wind belt varies considerably, but it is usually south of Taejon during January. In February the jet stream is located slightly further to the south over southern Japan and is even stronger with winds close to 230 kt. In March, although the mean position of the main axis of the stream remains the same, the jet band widens, bringing it closer to South Korea. The center of the jet is above Cheju-do with winds of 170 kt at around 40,000 ft (12,200 m).

In April the jet stream divides, with one axis located across North Korea and northern Honshu (the polar jet) and the other from Shanghai to Tokyo (the subtropical jet) (Figure 3-19). The velocity associated with both branches decreases as spring changes to summer. By July, the southern branch has moved northward to lie over South Korea, its speed weakened to 90 kt or even lower on occasions (Figure 3-20). This branch remains over South Korea through August and September, extending from Seoul to Tokyo at a height of approximately 40,000 ft (12,200 m). As fall progresses, the southern branch moves away to central China while the northern branch moves southward, first over North Korea and then further south with speeds increasing to 160 kt at 35,000 ft (10,600 m) (Figure 3-21). By December, both branches converge to form one main core over the Korea Strait.

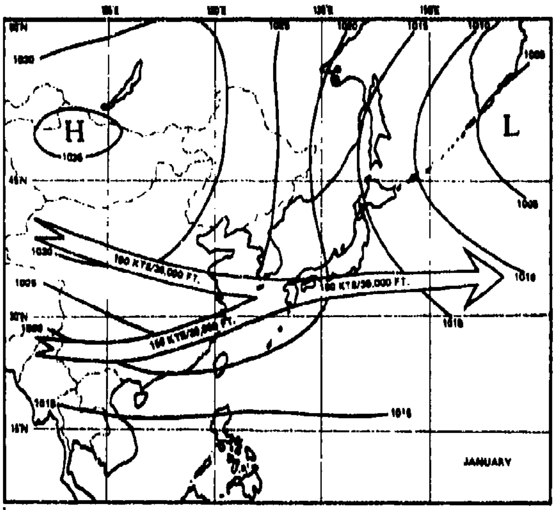


Figure 3-18. Mean position of the jet stream in January (from 1st Weather Wing, USAF).

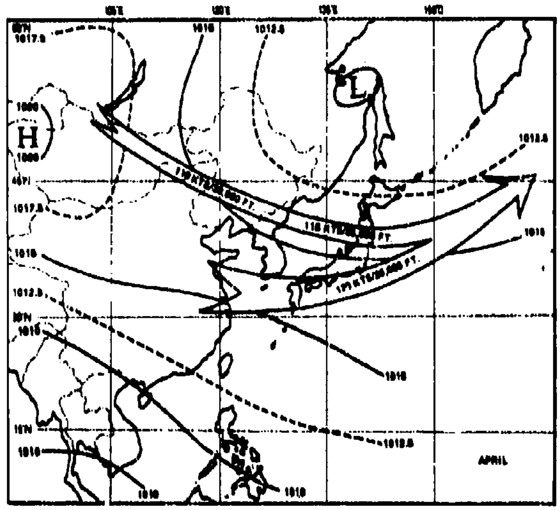
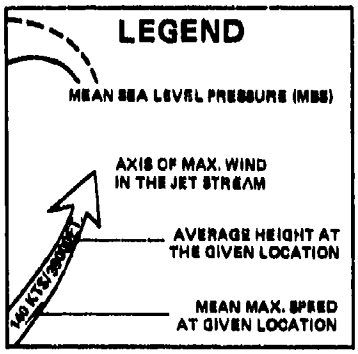


Figure 3-19. Mean position of the jet stream in April (from 1st Weather Wing, USAF).



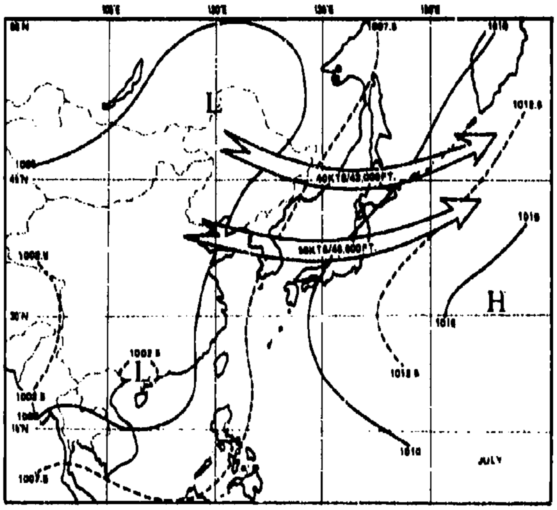


Figure 3-20. Mean position of the jet stream in July (from 1st Weather Wing, USAF).

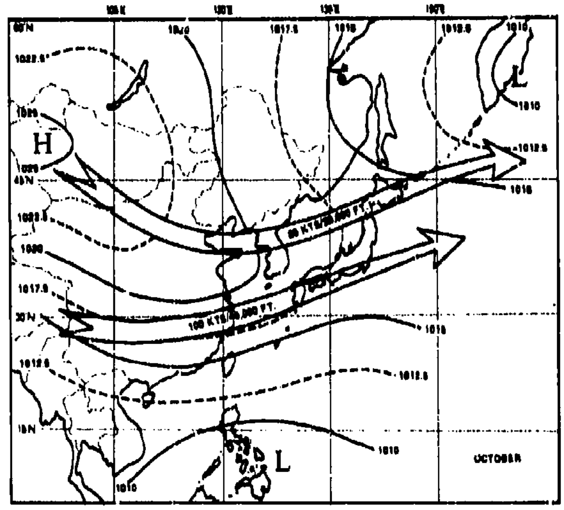


Figure 3-21. Mean position of the jet stream in October (from 1st Weather Wing, USAF).

The jet stream is at its lowest altitude and greatest velocity during the winter months. Its direction and flow in this region, as well as in other areas of the middle latitudes, governs the movement of low level pressure systems from west to east. Winter weather will generally originate on the west coast and move southeast. This steering effect of the jet, coupled with the funneling effect on surface winds as they pass between the Chiri Massif in the southwest and Mt. Halla on Cheju-do, produces high winds on the north coast of Cheju Island and surface wind velocities that average 17-19 kt.

Good correlation between the mean jet axis and trajectories of prevailing storms exists over the Korean Peninsula in summer. Irregular or anomalous jet stream behavior may be observed during any month, but it occurs most frequently during spring and fall.

3.3.5 Visibility - Fog, Haze, Smoke

Visibility over South Korea is generally good. Seasonal variations are large, with the lowest visibility usually occurring in summer, but regional variations are rather small. Diurnally, visibilities are lowest around sunrise and best in the afternoons throughout the year. Fog is generally the chief restriction to visibility in summer, but fog, haze and smoke are equally restrictive in winter with haze and smoke most prevalent near the industrial centers. Dust occurs primarily in winter, although the frequency of this restriction is low. Precipitation may affect visibility throughout the year, but the effect is most noticeable in winter when any precipitation is likely to fall as snow.

Visibility of less than 2½ mi (4 km) most often occurs during summer mornings throughout most of South Korea. During other hours in summer, especially in the afternoon, and during most hours in the other seasons, visibilities of less than 2½ mi (4 km) are reported on fewer than 10% of all observations. The major exceptions are the central and southwestern parts of the northwest hills and plains, where low visibilities are fairly frequent in the mornings during most of the year.

Visibilities less than 6 mi (10 km) are frequent, occurring at most locations as much as 40-70% of the time during the worst hours. During the afternoon period, visibilities greater than 6 mi (10 km) are reported as much as 90% of the time. Regional variations are not significant, but seasonal variations differ appreciably by place and time. Many localities have visibilities below 6 mi (10 km) most frequently in summer Generally, visibility is less than 6 mi (10 km) most often near sunrise and least often in the afternoon hours. Diurnal variations are usually smallest in winter, when daily ranges are mostly less than 30%, and largest in summer, when they can reach 60% at many locations.

Smoke and haze occur most frequently in winter and are at their worst in a cold, stagnant air mass. Damp haze can persist in summer, but the frequency of occurrence is generally small. Smoke and haze occur most often near the larger industrial areas, where annual averages are about 100-180 days. Elsewhere, haze and smoke occur on fewer than 50 days per year. Dust is noted occasionally, but it is reported on fewer than 10 days per year at most locations. This dust is usually brought over the area from the deserts of Mongolia and North China by strong winds aloft, and visibilities may be restricted over wide areas for several days.

Precipitation also reduces visibility, particularly in winter when it falls mostly in the form of snow. This snowfall can cause very low visibility, especially in the mountains; blizzards and snow storms will occasionally reduce visibility to near zero.

Fog, the chief restriction to visibility, varies in frequency throughout South Korea, depending on location and time of year. However, the annual number of days with fog is generally large, averaging 100-180 days. There are two main types of fog that affect South Korea, sea fog and radiation fog.

Sea fog forms over parts of the Sea of Japan and the Yellow Sea in late March through August, with maximum occurrences in June and July. This fog forms when relatively warm air flows over the cooler sea waters, and the lower layers of the air are cooled until condensation occurs. If the surface air flow is onshore, the fog may move inland for a considerable distance, especially on the western side of the Peninsula.

Radiation fog occurs throughout the year, but it is most frequent during the cooler months in protected areas, especially in river and mountain valleys. However, this type of fog usually dissipates by midmorning. The west coast experiences fog 22% of the time, compared to 7% on the east coast and 10% on the south coast. Thus, over an average year, the west coast can expect three times as many foggy days. The Seoul-Inchon area has the highest frequency of fog in the whole of South Korea, reaching a maximum frequency of 38% in July.

Typical pressure distributions by season for cases where the entire west coastal area is covered by fog are shown in Figures 3-22 to 3-25 and described by season below. These distributions indicate that warm, moist air arriving at the west coast from the south or southwest will frequently create a fog situation.

Winter. The strong Siberian high west of Lake Baikal exerts its influence southeastward, with sometimes a southward and eastward surge of air near the point 45°N, 112°E as a result of cyclogenesis in Korea Bay. When this occurs, the air over the west coast of South Korea generally becomes warmer and thick fog forms. However, under the direct influence of the Siberian high (without any modification from cyclogenesis) the air becomes cold, dry and fog-free, with some haze and smoke near the cities.

Spring. The low pressure cell that originates from the declining Siberian high is active during this period and is followed by the high from the southern region of China. As this system arrives at the west coast, thick fog is formed along the west coastal area.

Summer. The Peninsula is under the influence of the Kokasahara high as it reaches into the southern part of the country. When this occurs, there is fog throughout the coastal area and sometimes inland as well.

Fall. The Siberian high is reestablished with the decline of the low over China. The high begins its push eastward and is divided into southward and eastward influences by the cold front out of the low in the Sea of Okhotsk. Under this pressure distribution, there is much cloudiness and mist.

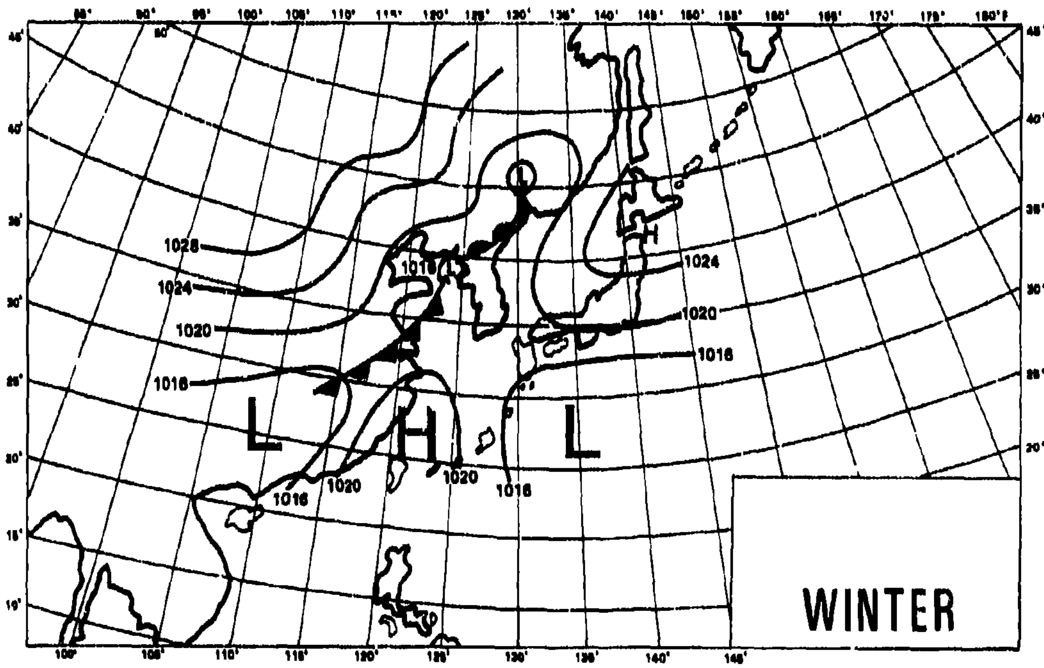


Figure 3-22. Typical winter pressure distribution for west coast fog (from ROKAF).

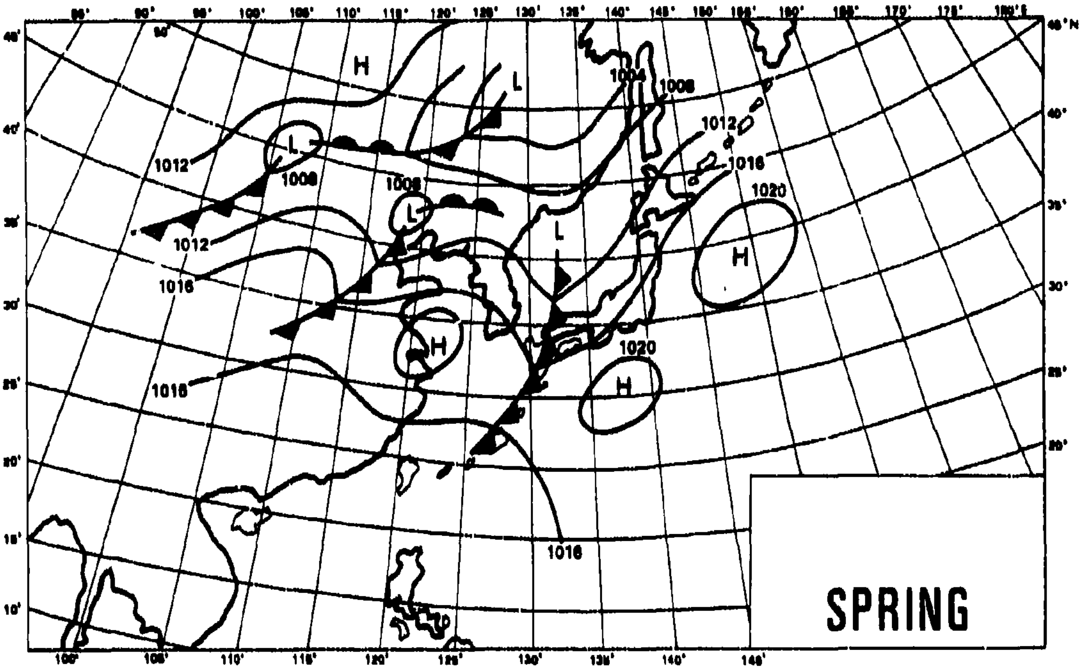


Figure 3-23. Typical spring pressure distribution for west coast fog (from ROKAF).

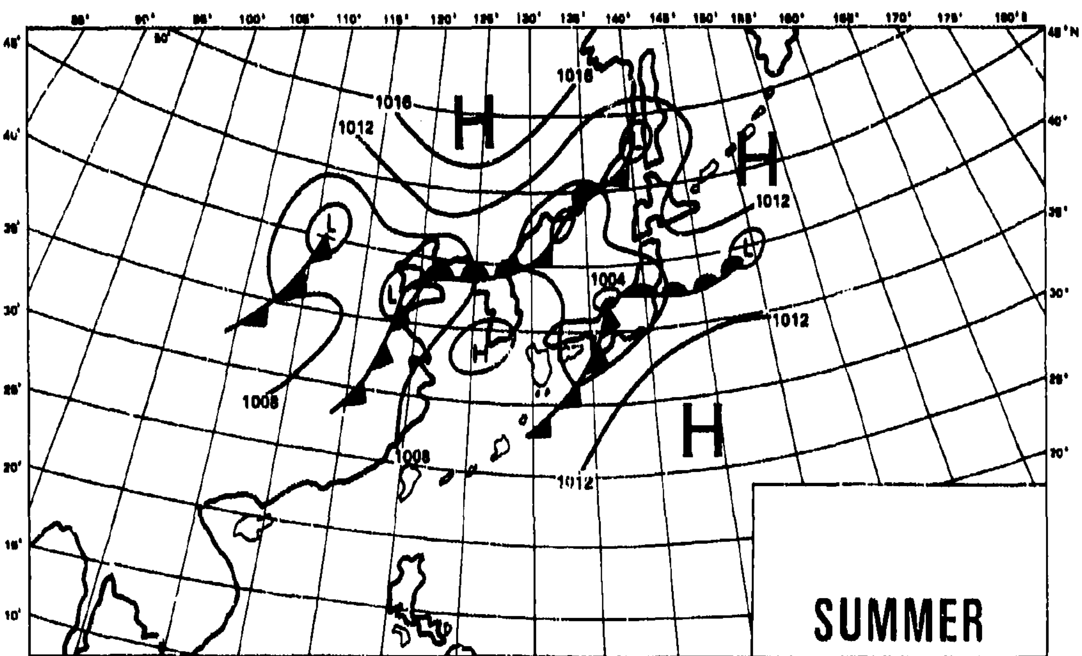


Figure 3-24. Typical summer pressure distribution for west coast fog (from ROKAF).

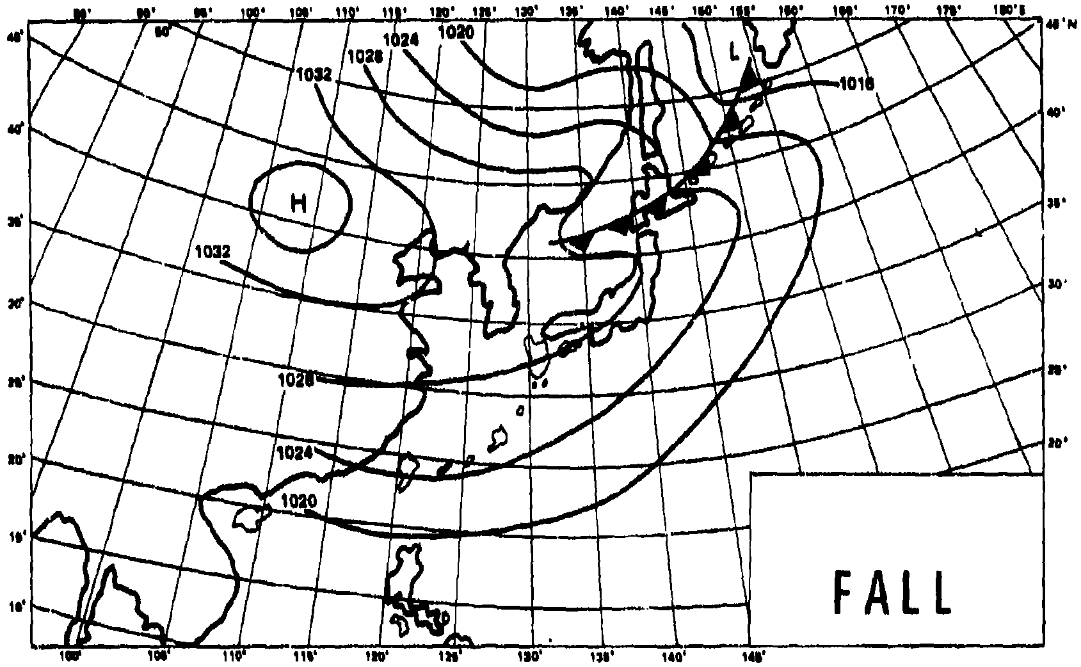


Figure 3-25. Typical fall pressure distribution for west coast fog (from ROKAF).

3.3.6 Cloud Cover

Cloudiness is quite extensive in summer over the entire Korean Peninsula, but skies are frequently clear in winter. The amount of cloud cover and its height above the ground are particularly important in planning air operations in such a mountainous country. Although there is no indication of large scale regional differences, the terrain configuration does cause local variations, especially in ceilings during the summer monsoon. Ceilings in the valleys are frequently higher than those over the mountains, which at times may be completely obscured by clouds; this situation obviously can be dangerous for low-flying or descending aircraft.

Regional variations in cloudiness are generally small, but seasonal changes are large. The moist air of the summer monsoon causes considerable cloudiness with mean amounts ranging mostly between 60% and 80%. In fall, cloud amounts generally begin to decrease as the dry winter monsoon replaces the moist summer monsoon. In the southwestern part of South Korea, minimum cloudiness is experienced during late fall or early winter, when cloud cover averages about 30% to 50%. Elsewhere, minimum cloudiness is experienced in winter with averages generally ranging from 30% to 55%. Cloudiness generally increases at all locations during spring and reaches the maximum in summer.

Diurnal variations of mean cloudiness are not great, generally less than 20%. Although the time of day when maximum and minimum cloudiness occurs varies both regionally and seasonally, there is a general trend toward maximum cloudiness during the daylight hours and minimum cloudiness at night. Table 3-5 and Figures 3-26 and 3-27 are included to show typical numbers of clear days. Approximately 150-200 cloudy days per year is the general rule at most locations; the mean annual number of clear days is generally 125-175.

Table 3-5. Monthly and annual number of cloudy days at selected stations in South Korea.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kangnung	4	6	10	10	11	16	20	16	13	7	6	6	125
Seoul	6	6	8	9	11	14	19	15	11	6	6	6	117
Inchon	5	5	8	9	12	14	18	14	11	5	5	6	112
Ullung-do	19	15	13	9	12	15	18	15	15	10	12	16	169
Chupungnyong	8	7	9	8	12	15	18	14	14	8	7	7	127
Pohang	4	6	9	9	11	15	18	11	13	7	6	4	113
Taegu	5	6	9	10	12	15	17	14	13	8	6	6	121
Chonju	9	9	10	10	12	16	18	13	12	7	8	10	134
Ulsan	5	7	9	11	13	17	18	14	14	8	6	5	127
Kwangju	10	9	10	10	12	16	19	12	14	7	7	9	135
Pusan	5	7	10	11	12	17	19	13	14	8	6	5	127
Mokpo	13	11	11	10	13	16	18	11	12	7	9	12	143
Yosu	5	6	9	10	12	16	19	11	14	6	5	4	117
Cheju	23	17	15	13	15	17	15	12	15	12	13	20	186

Cloud types over the Peninsula depend to a large extent on the synoptic situation. The dry winter monsoon produces cumulus and, occasionally, strato-cumulus clouds. In the southern part of the area, stratus and nimbo-stratus clouds, with cumulus imbedded, are associated with fronts and occasional low pressure centers. As the polar front moves northward, stratus and nimbo-stratus clouds predominate north of the front, and cumulus and cumulonimbus are often imbedded in these systems. South of the front, cumulus and cumulonimbus are the primary types. Altocumulus and altostratus occur most frequently during the "plum rains" (see Para. 3.2.3), generally in the vicinity of cyclonic activity.

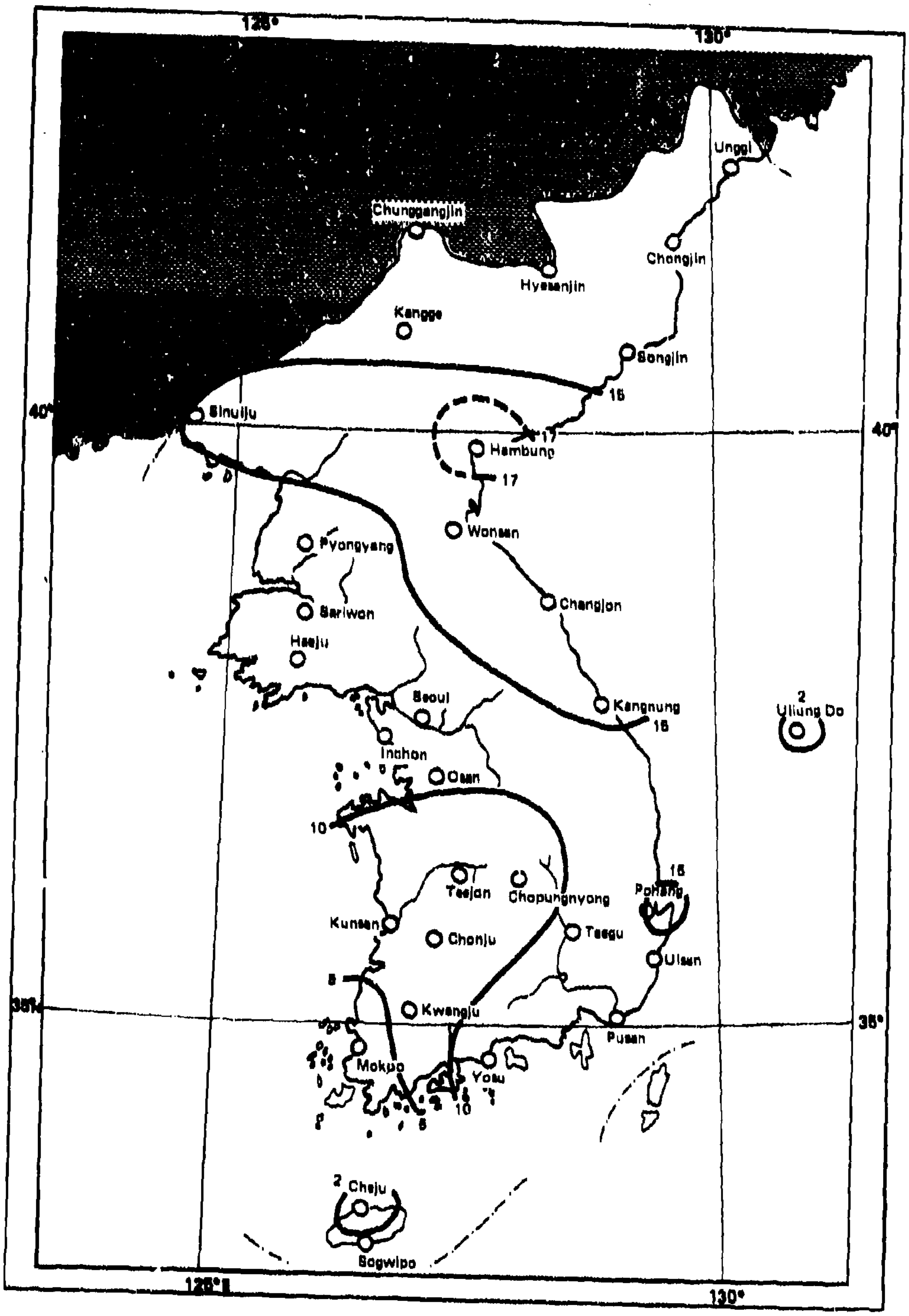


Figure 3-26. Mean number of clear days during January (from Climatic Atlas of Korea, 1962).

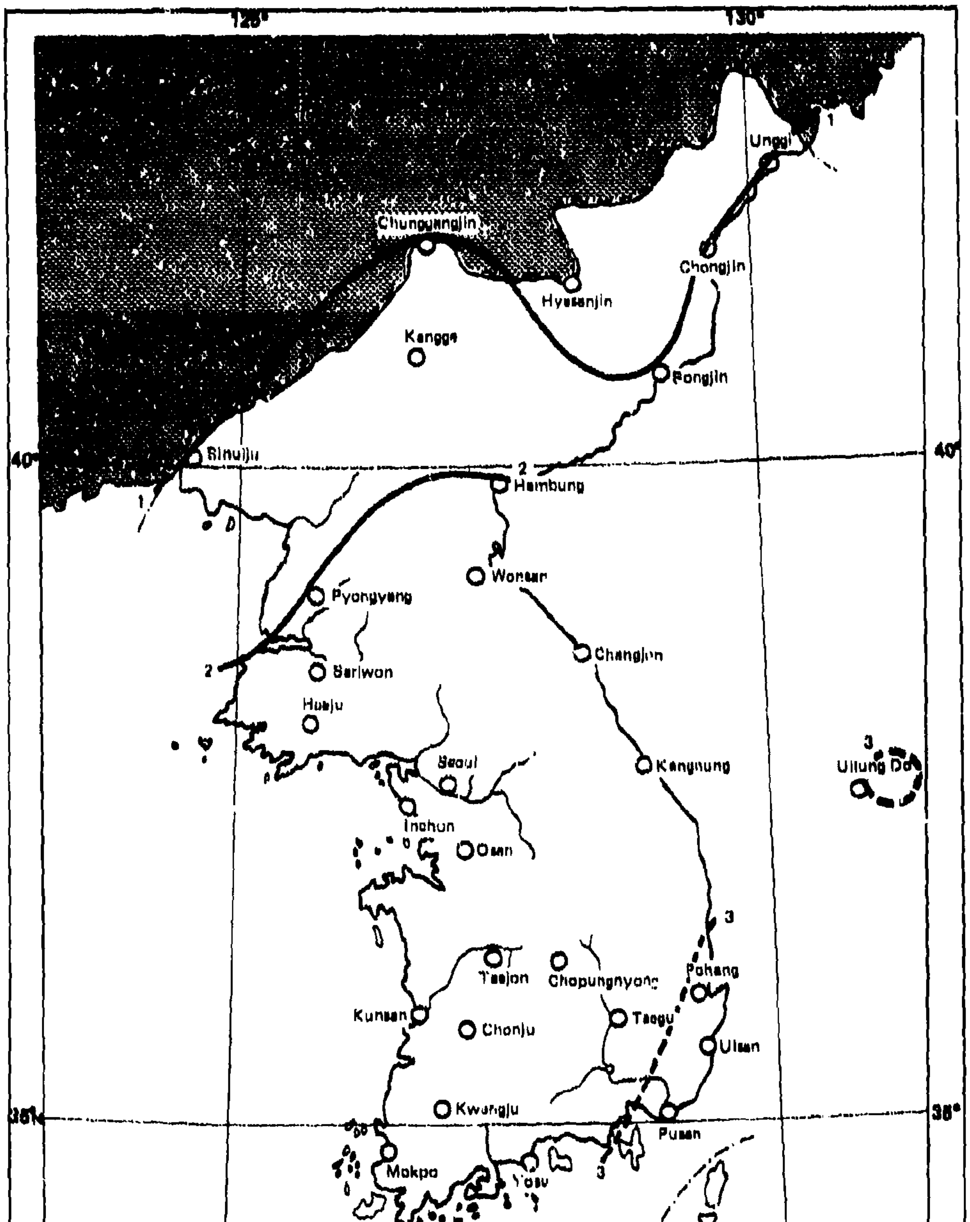


Figure 3-27. Mean number of clear days during July (from Climatic Atlas of Korea, 1962).

Ceilings less than 1000 ft (304 m) occur most often during the warmer months. However, frequencies are not large, mostly less than 15%, except during the early morning hours, when they range between 15% and 50% at many locations. In general, stratus clouds are the predominant cause of low ceilings throughout the year; because stratus clouds are most prevalent soon after sunrise, the low ceilings are most frequent during this time. During the day, the lower layers of the atmosphere are heated and most of the low clouds either rise or dissipate. Consequently, low ceilings are at a minimum during the afternoon hours.

Much of the low cloudiness that occurs over South Korea appears to be based at 1000-3300 ft (304-1000 m). As with mean cloudiness and ceilings less than 1000 ft (304 m), the frequency of ceilings below 3300 ft (1000 m) varies appreciably from summer to winter. Ceilings are below 3300 ft (1000 m) most often during June through August or September, with frequencies about 30-70%. In winter, these ceilings are reported on less than 30% of the observations at most locations. The major exceptions are the islands of Paengnyong-do (37°59'N, 124°40'E) and Ullung-do (37°29'N, 13°54'E) where high frequencies of 35-65% occur in most months both summer and winter.

3.3.7 Typhoons (Figure 3-28)

The typhoons that affect the Korean Peninsula generally originate east of the Philippines between 140°-155°E and 5°-20°N. The primary tracks are to the west, with recurvature to the northeast, although some are first detected in the South China Sea. These typhoons start traveling toward the southeast coast of China; some move onshore and are dissipated there, while others turn from west to north and then northeast. Of the average of one to four typhoons that form in June, about half travel north of Manila and reach China south of Hong Kong. Of the other half, a few move to the north China coast and the balance move west or south of Tokyo. These have little influence on Korean Peninsula weather. In July, August and early September, however, one or two typhoons may cross the southern half of the Peninsula. Past data indicate that the two periods of greatest probability are 11-20 July and 1-10 September, although a threat exists throughout the whole three months. After the middle of September, the main typhoon track moves east over Japan and the threat to the Peninsula subsides.

By the time typhoons reach South Korea, they have generally lost wind strength and most of the damage is caused by the intense rains. However, Typhoon Sarah in 1959 was a notable exception to this general statement (see case history following). September typhoons are particularly feared because the heavy rains flatten the heading rice as well as burst dikes in the flooded paddies and along streams swollen by monsoon rains. Flood damage is particularly severe in the valleys where the rivers are estuarine and runoff from torrential downpours pours into riverbeds already swollen by high tides.

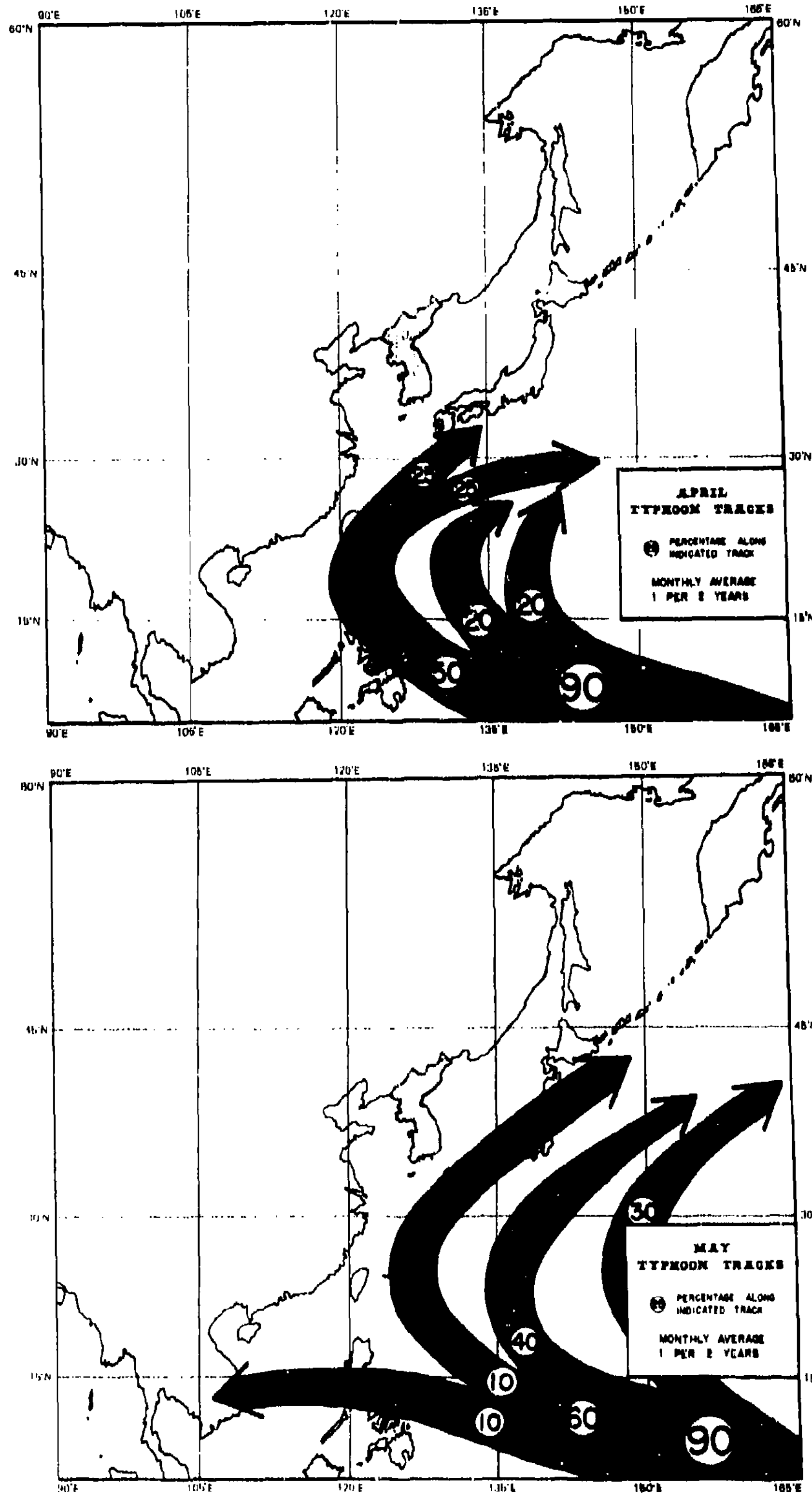


Figure 3-28. Typhoon tracks for the northwest Pacific, April-November.

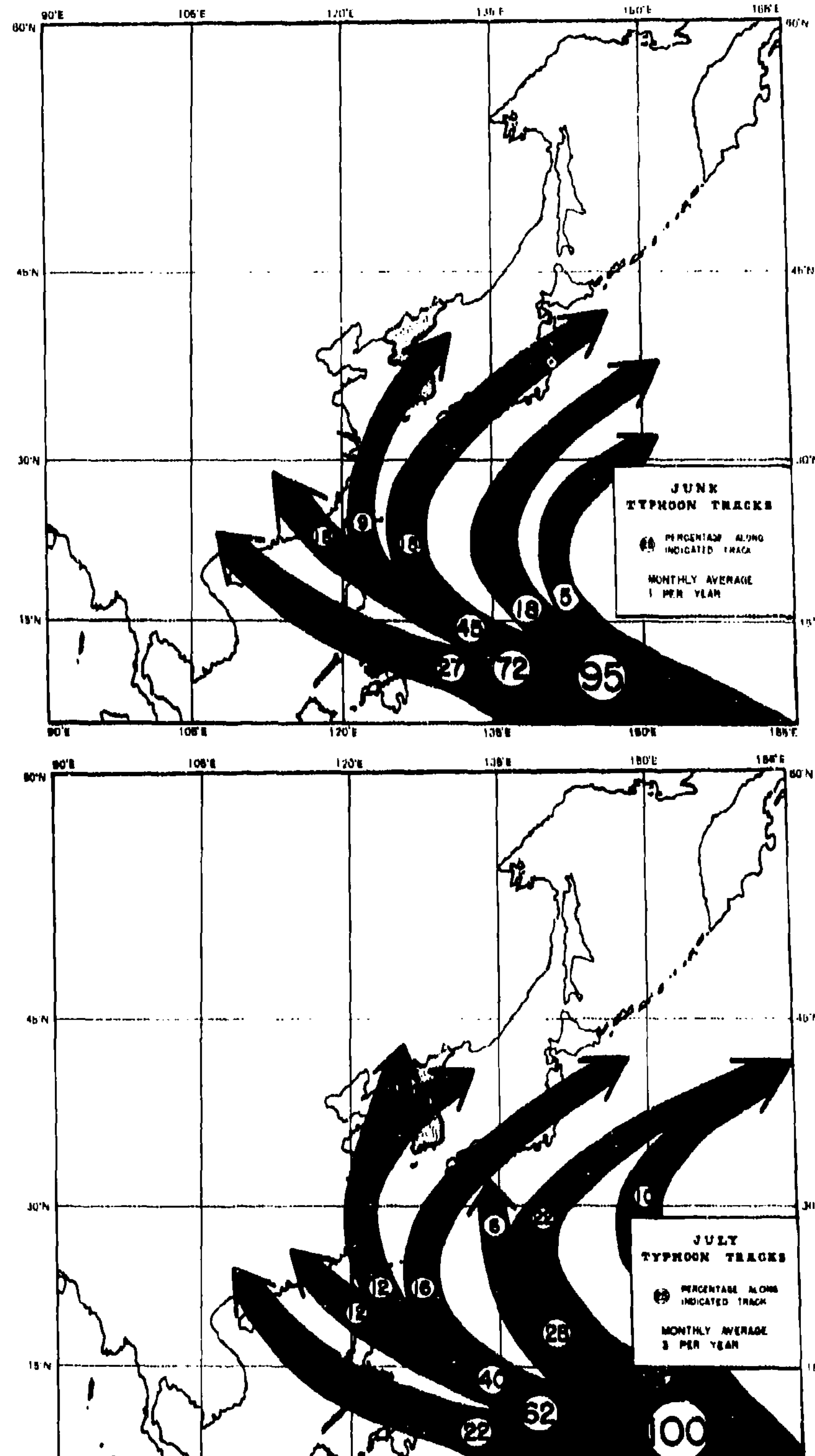
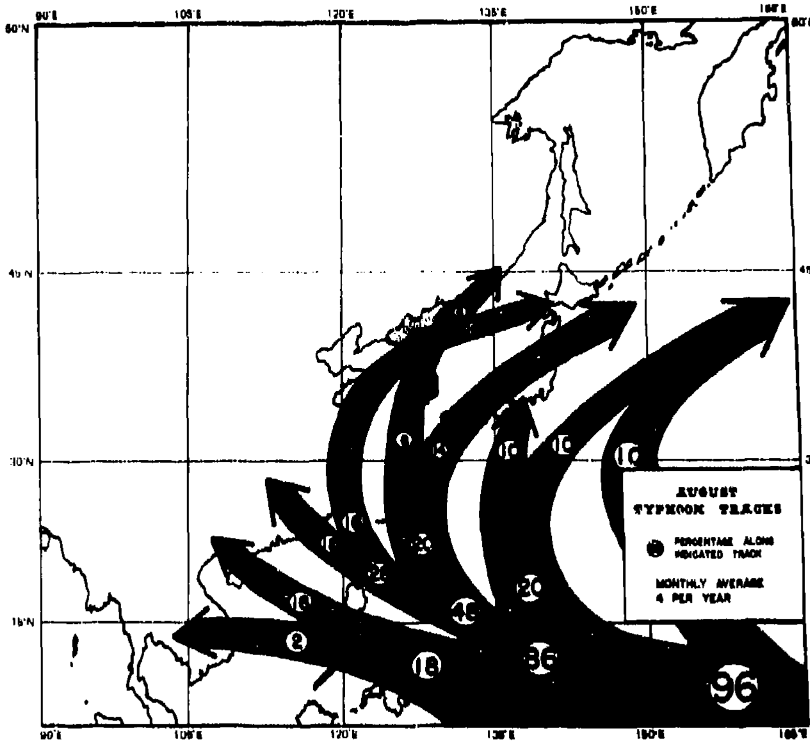


Figure 3-28 continued.



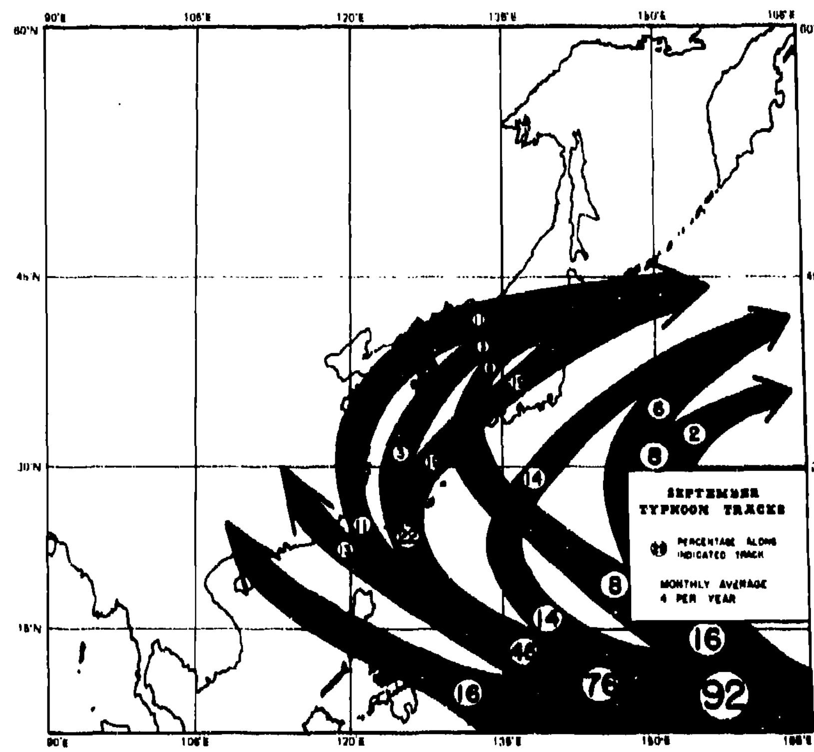


Figure 3-28 continued.

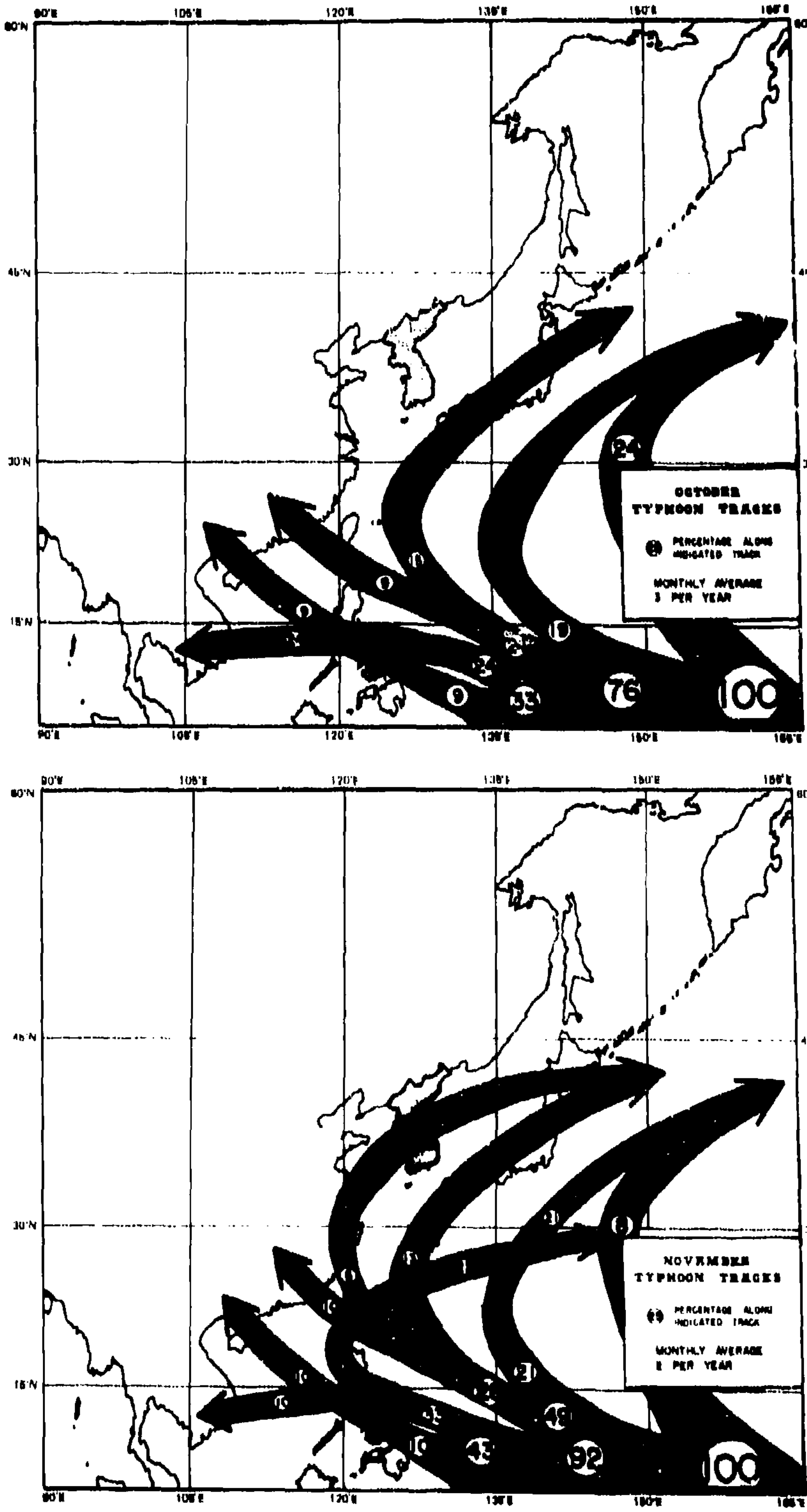


Figure 3-28 continued.

Typhoon Sarah, 11-18 Sep 1959. This typhoon was the worst such storm to hit the Korean Peninsula in 50 years. Sarah left 669 persons dead, 259 missing, thousands injured, and more than 782,000 persons homeless.

Early on 10 Sep, Tropical Storm Nora in the South China Sea, Tropical Depression Ruth midway between Guam and the Philippines, and a suspect area north of Ponape, all lay along the intertropical convergence zone (ITCZ). By 1200Z on 10 Sep, Ruth had dissipated; the following day at 0200Z, reconnaissance aircraft in the suspect area located a center 70 n mi (130 km) east of Guam. It was named Tropical Depression Sarah and warning No. 1 was issued for center winds of 30 kt. Subsequent fixes by the same aircraft indicated a rather indefinite situation with several small centers. However, it was possible to determine by land radar that the primary center (Sarah) passed just north of Guam at 1000Z on 11 Sep; the island experienced only light gusty winds and occasional showers. By 2000Z on 11 Sep, Sarah had become a fairly well defined circulation and had reached tropical storm intensity; 12 hours later, at 0800Z on 12 Sep, she was a full-fledged typhoon with center winds of 65 kt.

Sarah followed a rather classic parabolic track that took her directly over the island of Miyako Jima and just a few miles west of Pusan, South Korea. Sarah passed over Miyako Jima at approximately 0900Z on 15 Sep with maximum sustained winds of 106 kt and gusts to 130 kt. Although Sarah passed 150 n mi (278 km) to the west of Okinawa, Naha reported winds of 73 kt. After Sarah raked the southeastern tip of South Korea, she began to weaken and accelerate; further weakening took place over the Sea of Japan. By 0600Z on 18 Sep, over Hokkaido, Sarah had become extratropical and the final tropical warning was issued.

Sarah was the third most intense typhoon of 1959 in the Western Pacific. Surface winds reached a maximum of 165 kt and the surface pressure dropped to a minimum of 905 mb. Sarah recurved slightly farther west than is normal for mid-September, which caused Miyako Jima to bear the brunt of the onslaught, but Sarah was still South Korea's worst typhoon in half a century. Sarah followed a very stable path, however, and only minor forecasting difficulties were encountered; a total of 30 warnings were issued covering a period of eight days.

In addition to the casualty list cited earlier, the South Korean Ministry of Social Affairs reported property losses exceeding $100 million. The loss included 14,000 homes destroyed and 2800 fishing vessels sunk; another 2600 vessels were badly damaged and 313,000 acres of farmland were flooded. Reports from U.S. authorities said military installations in the Pusan and Taegu areas suffered $900,000 damage, with damage to the port of Pusan exceeding $100,000. The Pusan area was hit the hardest; police reported 25,834 persons homeless from floods and tidal waves, and an estimated 15,379 homes washed away, damaged or destroyed (U.S. FWC/JTWC, 1959).

3.3.8 Thunderstorms and Turbulence

Thunderstorms are infrequent over the Korean Peninsula except in the mountains. The mean annual number of days with thunderstorms range from fewer than five at many places throughout South Korea to over 20 at several places in North Korea; frequencies are somewhat higher in the mountains. During late spring through early fall, the period of maximum thunderstorm activity, very few localities have more than five days per month with thunderstorms, and most places have three thunderstorm days or less. Usually they produce surface gusts in the 25-40 kt range with small hail 1/4-3/8 inches in diameter. Thunderstorms seldom occur during the winter monsoon.

Thunderstorm activity may be frontal, air mass or orographic. Frontal thunderstorms are most likely to occur during early summer and fall; air mass thunderstorms are a result of convective activity and occur most frequently during the hot afternoons of summer. Orographic thunderstorms can occur any time that warm, moist, unstable air moves up a mountain slope. Frontal and orographic thunderstorms occasionally may be more severe than air mass thunderstorms because of the additional lift supplied by the fronts and mountains. Data are not available concerning the vertical development and tops of thunderstorms; however, tops can be expected to reach 50,000 ft (15,240 m) on occasions.

Moderate to severe turbulence can always be expected in the vicinity of thunderstorms and may extend to great heights. Although thunderstorms occur most frequently in late spring through early fall, these storms can usually be avoided by aircraft; a more dangerous situation may be encountered in spring, when thunderstorms are often masked by or imbedded in other clouds.

Because South Korea is a mountainous country, mountain waves may produce occasional severe turbulence that can affect flight operations. A wave condition generally occurs when strong winds blow across a mountain range; the actual wind direction may vary somewhat, but the strength of the wave diminishes rapidly as the wind becomes more nearly parallel to the mountains. The mountain wave can sometimes be identified by lenticular and roll clouds on the lee side of the mountains and by cap clouds over the peaks. However, if the air is very dry, there may be no visible evidence of the turbulent wave. The most dangerous features of the wave are the turbulence in and below the clouds and the downdrafts immediately to the lee of the mountain peaks, which may occasionally be obscured. In addition, pressure changes under wave conditions may cause large errors in the altitudes shown by an aircraft's altimeter.

Light clear-air turbulence can be expected on hot days below approximately 5000 ft (1524 m) over flat terrain; it may achieve moderate intensity over rough mountainous terrain. This turbulence is caused by surface heating of the low level air on hot summer days. During the hottest months of the year,

thermal turbulence may extend several thousand feet above the surface. Clear air turbulence at high levels over much of South Korea is virtually inevitable. Because of the rapid change in wind speed both vertically and horizontally in the vicinity of the jet stream, severe turbulence should be expected, especially during winter.

3.3.9 Floods and Droughts

Extensive floods, mudflows and landslides are generally caused by the unusually heavy rainfall that occurs during June through September. Nearly all large streams are in flood after heavy rains, and small streams become raging torrents. Typhoons that pass close to the Peninsula inevitably produce flooding. Flash flooding, especially in the mountainous interior, occasionally results from heavy thunderstorm activity.

Droughts occur infrequently, however, and usually when the polar front and associated rainfall remain south of the Peninsula for unusually long periods; during this time the air is under the influence of the dry air flowing off the Asian continent. Intense droughts occurred in 1967 and 1968.

3.3.10 Dust Storms

The dust storms that occasionally affect the Peninsula (actually dust clouds that often extend upward several thousand feet) are raised at some distant location and then drift over the country. They are most frequent during the winter months when the winds pick up large quantities of dust from the deserts of Mongolia and northern China. This phenomenon largely affects areas in North Korea, particularly the northwest part of the northwest hills and plains, but dust occasionally affects South Korea as well. During late winter and spring, dust from the Gobi Desert may be carried south by active cold fronts from the northwest and cause reduced visibility. In spring when there is a strong northwest or westerly flow over Manchuria and China, yellow dust will sometimes be carried as high as 15,000 ft (4572 m) and reduce flight visibility to as little as 2 mi (3 km).

3.3.11 Icing and Freezing Levels

Surface icing is depicted in Figure 3-29, which shows earliest and latest freeze dates and mean thaw dates for the rivers and surrounding seas of South Korea. Sea ice is mainly a problem in North Korean waters.

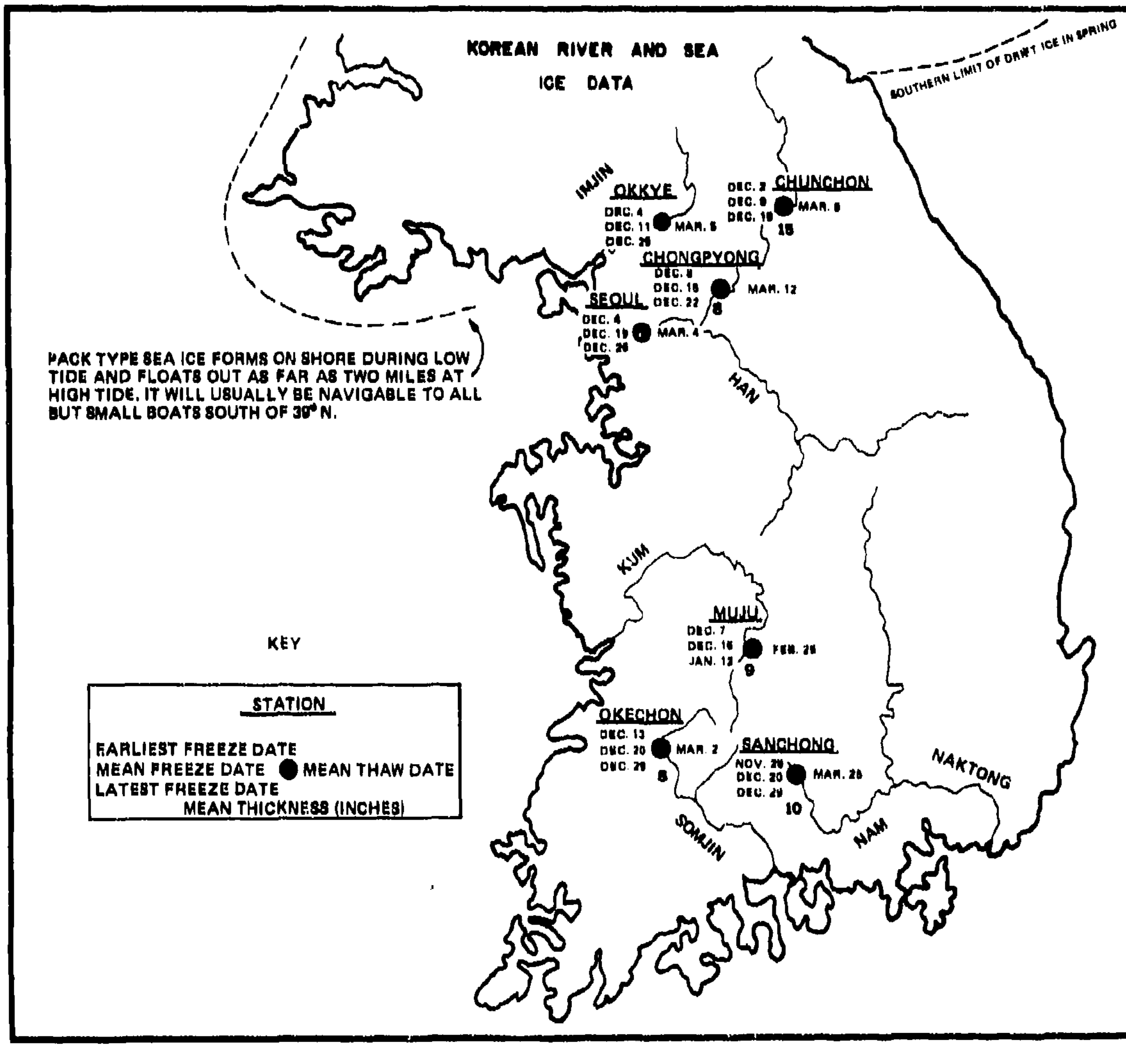


Figure 3-29. Freeze and thaw dates for South Korean rivers and adjacent sea areas.

Aircraft icing is generally not a frequent problem during the winter because of the relatively dry winter air mass affecting the Peninsula; however, infrequent severe icing conditions may be encountered in frontal zones and well developed cyclones. Icing is most hazardous during spring and fall when the polar front is migrating across the Peninsula; during this time the 0°C level lies anywhere between the surface and 9000 ft (2743 m) and moist tropical maritime air prevails south of the front (in summer the 0°C level is generally near 15,000 ft/4572 m). Rotary wing aircraft are particularly prone to icing in these conditions; in most cases the icing is of the light to moderate rime variety. Flight through clouds at levels between the 0°C and -20°C isotherm, particularly in convective cumulus clouds, will usually result in severe, clear icing conditions. Frost conditions or freezing fog may occur in winter after frontal passage during the evening hours (mean dates for frost conditions are given in Para. 3.3.1).

During summer and under stagnant air mass conditions in other seasons, the daytime freezing level will rise 500-1000 ft (152-304 m) higher than at night with the highest diurnal peak occurring about 2000 local time.

During late fall and early spring, the freezing level will appear to jump from the surface to 4000-5000 ft (1219-1524 m) MSL near noontime as the low level inversion is wiped out by daytime heating.

Another frequent phenomenon during the spring and fall transition months is the advent of warming aloft and cloudiness preceding a major storm system from the west or southwest after a night of extensive radiational cooling over the entire Peninsula. Under such conditions, most areas of South Korea will have temperatures below freezing on the surface with temperatures above 0°C from 1000 ft (304 m) to between 4000 and 8000 ft (1219-2438 m) and steady precipitation falling. A narrow or thin layer of air below freezing will persist at or just off the surface for three to six hours after sunrise and/or the onset of rain and may not be apparent from the upper air soundings.

3.3.12 Astronomical Data

Appendix B contains a series of charts that provide a convenient reference for determining, with only slight error, the times of sunrise and sunset at any point on the Korean Peninsula and surrounding sea-land regions.

To use the charts, simply locate the point where sunrise or sunset times must be known, and interpolate between the solid/dashed lines. The solid lines are for sunrise, the dashed lines for sunset. Both are spaced at 10-min intervals from a given ZULU time (LST in Korea = ZULU time + 9 hrs).

3.4 OCEANOGRAPHIC CLIMATIC DATA

3.4.1 Ocean Currents

There are four major ocean currents off the shores of the Korean Peninsula, as shown in Figures 3-30 and 3-31. The Liman Current is cold because it originates off the northeast coast of Asia near Sakhalin Island. The Tsushima Current flows from different sources according to the season of the year and is named after the Tsushima Islands. The Yellow Sea Current flows with variable speeds and directions. The Kuroshio Current flows northward into the Korea Strait, bringing tropical water from the East China Sea.

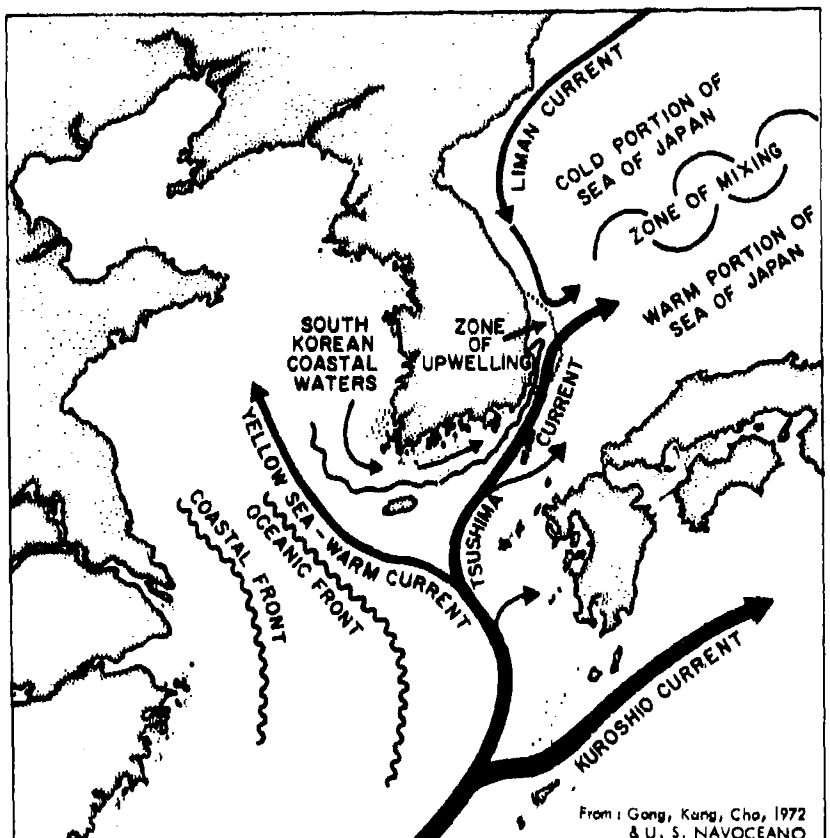


Figure 3-30. Summer ocean currents in the seas around the Korean Peninsula.

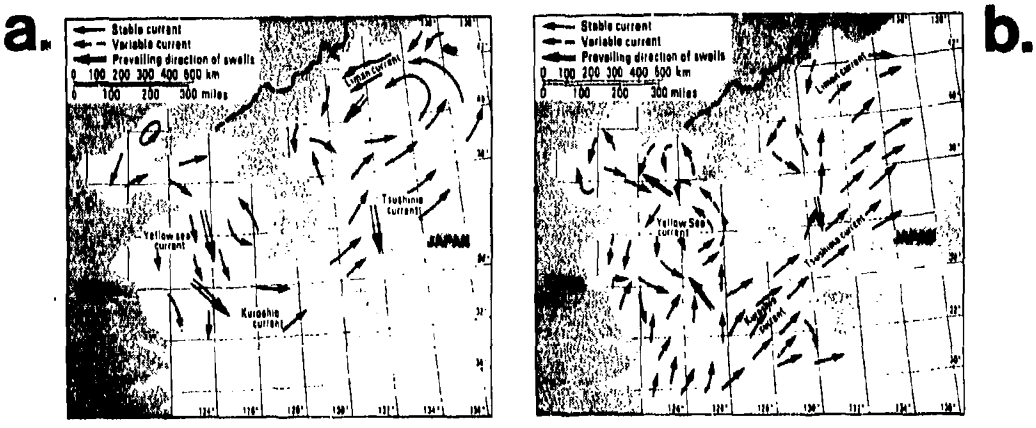


Figure 3-31. Ocean currents off the Korean Peninsula in (a) winter and (b) summer (from Bartz, 1971).

In winter (Figure 3-31a), the Yellow Sea and Liman Currents are at their strongest and are driven south along the west and east coasts respectively by the northerly winds. The Yellow Sea Current moves as far south as Mokpo (34°47'N, 126°23'E) at an average speed of almost 1 kt. On the east coast, the Liman Current, although not quite as fast moving at this time of the year, penetrates south of the 38th Parallel as far as Chumunjin and occasionally Pohang. Here, amidst considerable turbulence, it descends beneath the northward-flowing warmer Tsushima Current. At this time of the year, the Tsushima Current takes its origin from the Kuroshio Current bringing tropical waters northward. The current is powerful through the Korea Strait, moving at about 1 kt, but slackens and shallows as it proceeds northward along the east coast.

Thus, in winter, the south and southeast coasts are paralleled by warm currents while the waters off the west coast are colder because of the direction of flow of the Yellow Sea Current and the shallowness of the Yellow Sea. The effect on land temperatures is not as great as it would be if the prevailing winds were onshore, but the warmer ocean surfaces still help make Pusan and Pohang 10-12° F warmer than Seoul. The effect of the ocean currents in producing these warmer temperatures cannot be isolated from the influence of the more southerly latitude, the shelter provided by the Sobaek Mountains from the cold blasts of the north, and the foehn effect upon the northerly winds as they descend into the Naktong basin. The combined result is that the winter isotherms bend northward along the south and east coasts, giving Pohang slightly higher winter temperatures than Kunsan, and Kangnung considerably milder winters than Seoul.

With the weakening of the northerly winds, the Yellow Sea Current becomes variable in speed and direction by the end of March. This effect is not felt in the Liman Current until May because it is further north. As the northerly currents weaken, the Kuroshio becomes stronger, reaching maximum speeds of 1-2 kt and a mean temperature of 68°F (20°C) in June. At the same time, the Yellow Sea Current is reversing its direction along the southwest coast and beginning to move northward along the western shores. The Tsushima Current becomes more extensive and influences part of the domain of the Liman Current. By July, the Tsushima has become the strongest current, with the source of most of its water in the cool Sea of Japan rather than the Kuroshio (Figure 3-31b). Movement of the surface water away from the coast also causes an upwelling effect of bottom water, so that temperatures in the ocean off the east coast are lower than those off the west coast in summer. More and more warm water is pushed northward in the Kuroshio, temperatures in that current being about 76°F (24.5°C), compared with 50°F (15.5°C) in winter. The effect of the warm currents off the coast in the summer is to reinforce the heat and humidity of the southwest monsoon. The Yellow Sea Current develops into closed cyclonic circulation by July, which causes an upwelling effect in the central area and provides conditions favorable for sea fog formation.

3.4.2 Sea Surface Temperatures and Mixed Layer Depths

Sea Surface Temperatures. The 12 charts given as Figure 3-32 illustrate monthly averages of the sea surface isotherms in °F and show the east coast to be warmer than the west coast in winter because of the warm branch of the Kuroshio Current that flows northward along the east coast. In the vicinity of latitude 37-40°N, this branch meets head-on with the cold Liman Current (which flows southward along the coast of North Korea from Vladivostock, as shown in Figure 3-30); because of this confluence, the coastal area north of the Wonsan Gulf experiences much fog in the spring. The conversion table shows equivalent °C/°F temperatures.

TEMPERATURE CONVERSION TABLE							
(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)
−2	28.4	8	46.4	18	64.4	28	82.4
−1	30.2	9	48.2	19	66.2	29	84.2
0	32.0	10	50.0	20	68.0	30	86.0
1	33.8	11	51.8	21	69.8	31	87.8
2	35.6	12	53.6	22	71.6	32	89.6
3	37.4	13	55.4	23	73.4	33	91.4
4	39.2	14	57.2	24	75.2	34	93.2
5	41.0	15	59.0	25	77.0	35	95.0
6	42.8	16	60.8	26	78.8	36	96.8
7	44.6	17	62.6	27	80.6	37	98.6

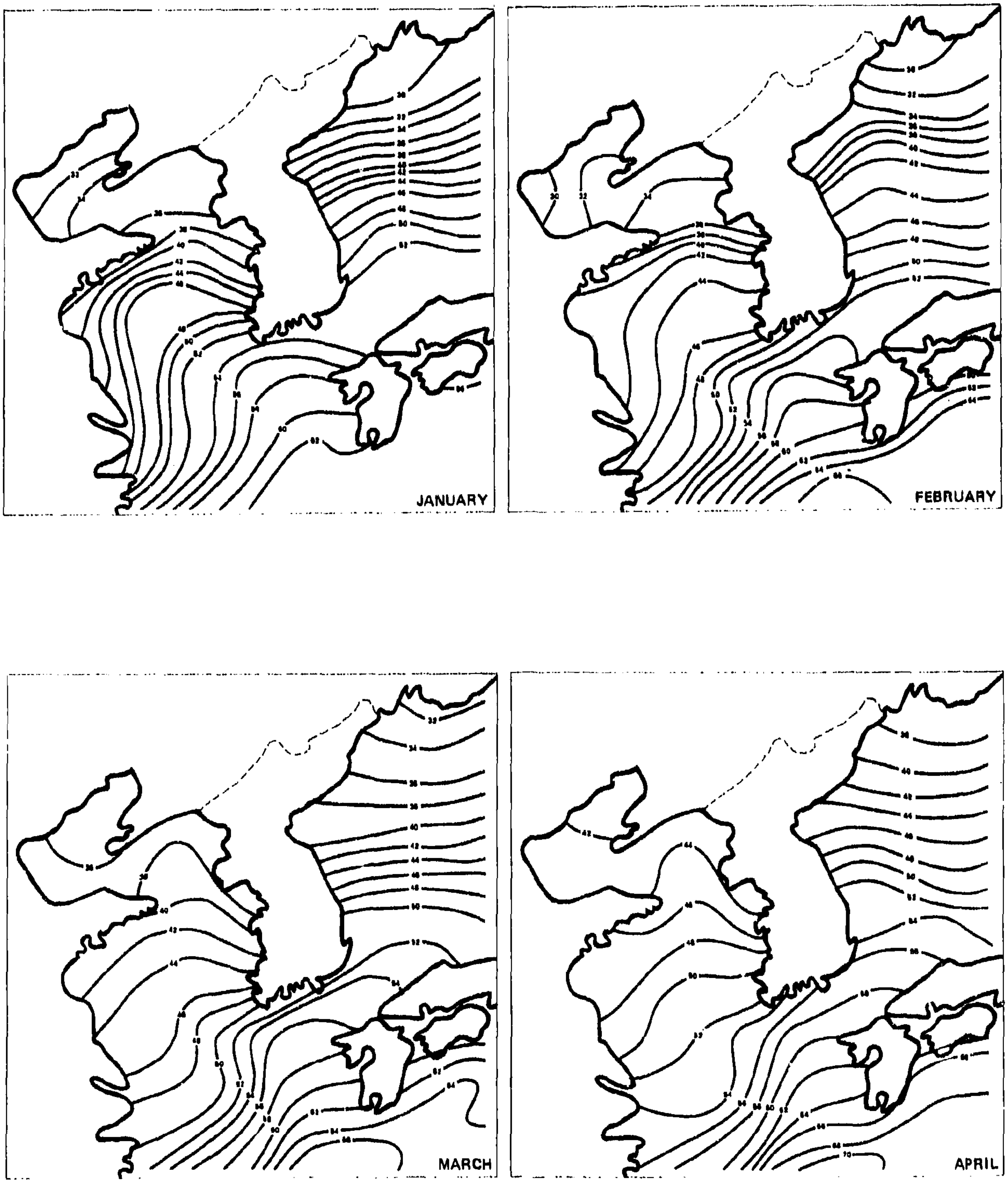


Figure 3-32. Mean sea surface temperatures (°F) for the months of January through December (from 1st Weather Wing, USAF).

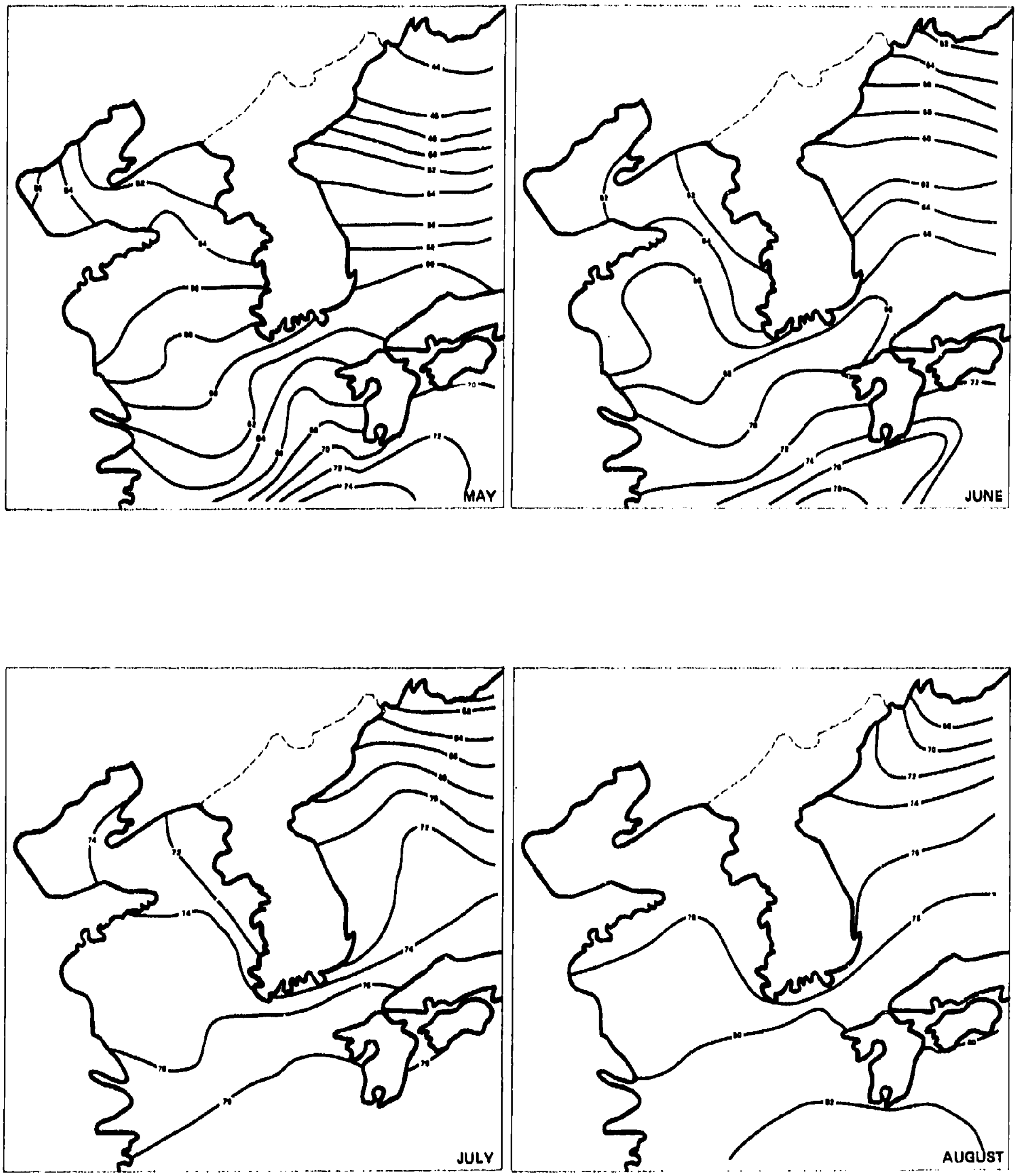


Figure 3-32 continued.

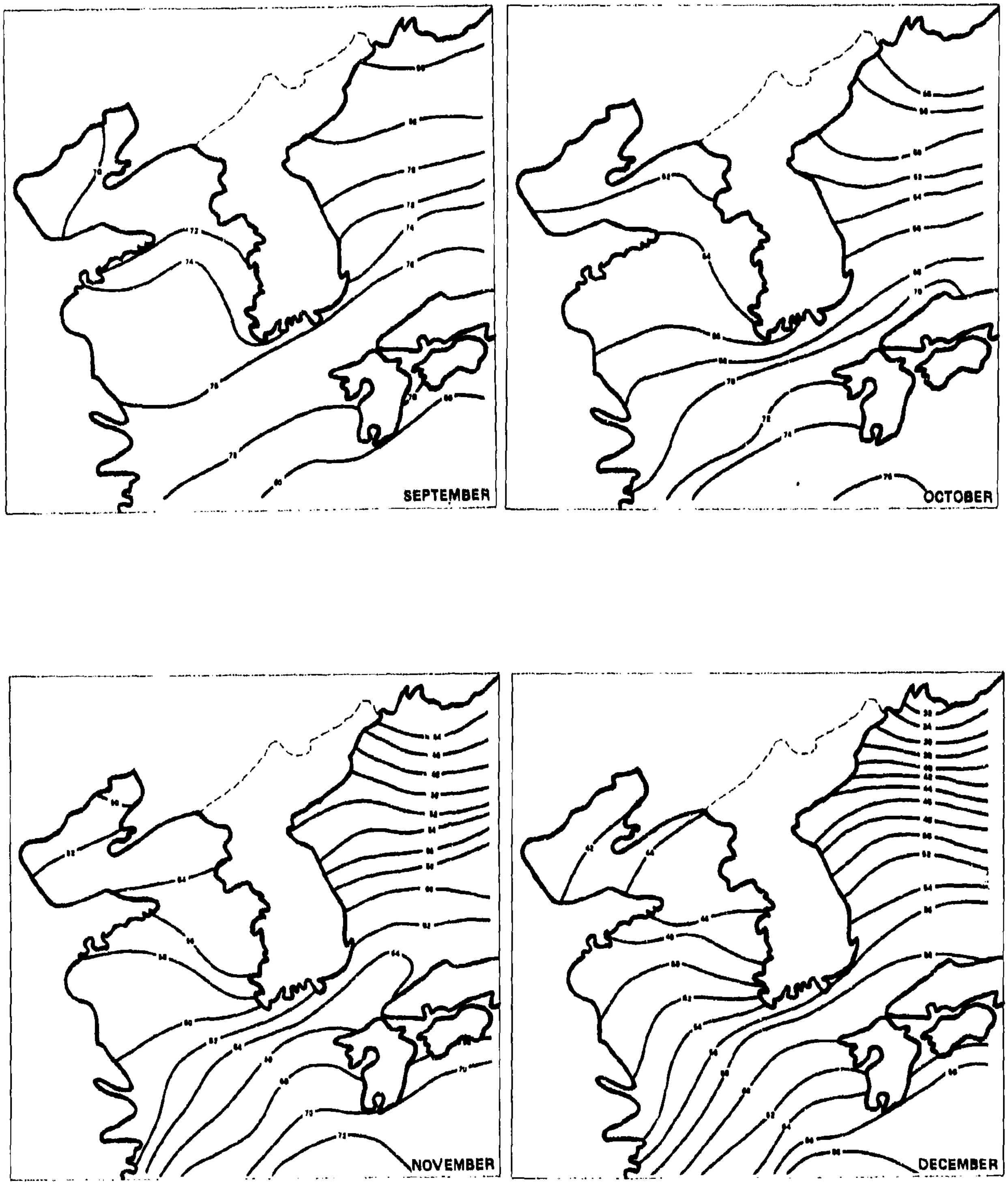


Figure 3-32 continued.

Mixed Layer Depths (MLD). In the summer regime, June through August, MLD's tend to be shallow (less than 100 ft/30 m), primarily because of the large positive air-sea temperature differences; these are especially evident over cooler waters in the Yellow Sea and Sea of Japan. Cold Arctic water and counter-currents near the Kuroshio Current are subjected to long periods of heating, creating negative surface gradients and shallow MLD's. The cool water has a relatively low velocity, so heating is not deterred by advection.

Throughout July, the shallow continental shelf water in the Yellow Sea experiences very shallow MLD's (less than 50 ft/15 m) because of the build-up of surface energy.

A second region of potentially shallow layer depths is the zone between cold and warm (Kuroshio) water masses, hereafter called the "transition zone." Along the boundaries of contrasting water masses, overrunning warm water creates a negative gradient and shallow MLD's.

During the fall regime, September through November, the cold seaward air flow provides a negative air-sea temperature difference that promotes convective mixing. As the northwest monsoon develops, wind mixing continues to deepen the MLD's. By the end of the regime, MLD's in the seas around the Peninsula are everywhere greater than when the season began. The transition zones continue to experience negative gradients and shallow MLD's of 100-150 ft (30-45 m).

In contrast to summer, the winter regime has predominately deep MLD's in middle and high latitudes due to convection. The cold Arctic water and counter-currents that were heated in the summer are now cooled and convection produces deep MLD's. This is the result of the negative air-sea temperature difference normally present in winter. Cold isothermal waters moving slowly from the Arctic are not heated at the surface as the air temperature is usually as low as or lower than the sea surface temperature. The cold waters retain their deep layers during advection.

The Kuroshio Current will also deepen due to convection as it moves north into mid latitudes. The amount of cooling in the stream is limited by the rapid advection of warm water. Mechanical wind-mixing is also increased, which contributes to deeper MLD's. Again in winter, transition zones occur between warm and cold water masses and are potential locations of shallow layer depths. All the seas around the Peninsula continue to increase the mixed layer to 200-300 ft (60-90 m), especially in the Sea of Japan where 400 ft (122 m) MLD's are common.

The spring transition season, March through May, fosters some unique MLD characteristics. As the spring heating begins in the tropics and progresses northward, cool water begins to heat at the surface. The warming gradually

moves north and the layer depths slowly decrease. For a short period in April, layer depth charts show both summer and winter conditions simultaneously. The seas around the Peninsula reach their maximum MLD at this time, and MLD's in the shallow seas are then rapidly wiped out by surface heating. As advection of the major currents continues, MLD's decrease until only scattered pockets of deep layers exist.

Figures depicting selected ocean data for Korean Peninsula waters are given in Appendix C. These data include mean monthly sound-speed/depth and temperature/depth profiles, as well as mean monthly depths to the top of the thermocline.

3.4.3 Sea, Swell and Surf

"Sea" is defined as waves that are produced by localized winds and move in the same direction as these winds. "Swell" is defined as wind-generated waves that have moved beyond their source region.

The predominant wave-generating winds in the region of the Korean Peninsula are controlled principally by two major pressure systems, the continental high and the continental low. The former develops over Asia in winter, the latter in summer. The resultant air flow from/to these pressure centers is monsoonal, i.e., northerly during winter and southerly during summer. The winter monsoon, with its steeper pressure gradients, is a steady air current, while the summer monsoon is weaker and less persistent. Cyclonic depressions, although most common during the transition season, also induce short-range changes in the monsoonal flow.

Local influences such as topography and land/sea breezes are important in wave modification insofar as they may divert the monsoonal flow to some extent. In nearshore waters of this area, windward of islands, land and sea breezes reinforce the monsoonal flow during the day and retard or reverse the flow during the night. Leeward of islands, the opposite diurnal trends occur. Therefore, sea and swell conditions for this area are a direct result of the general circulation modified by local influences.

The nearshore bottom topography is important in modifying waves as they approach the beach. Portions of shallow water waves passing over depressions on the bottom move faster than portions on either side. Consequently, wave fronts diverge over such depressions and lower wave heights result. Conversely, underwater ridges nearshore may increase wave heights immediately over the ridges. Thus, changes in wave height serve as an indication of underwater topography near the shore. Islands lying in the path of waves cause refraction around the sides of an island; the waves then may meet on the lee side of the island and pass through each other, producing a confused cross sea.

Lack of both sea and swell data for the area impose limitations on the presentation of meaningful sea and swell graphs. Fall and winter, represented by the months of November and February respectively, are the seasons of roughest seas and heaviest swell with the roughest seas found along the east coast. Although high swell has been reported elsewhere during all seasons, low swell is the most prevalent. Calm seas with no swell occur most often during the transition periods and in conjunction with the weak summer monsoon. Spring, represented by May, is the calmest season for the entire area, and at that time more than 2/3 of all observations report waves less than six feet in height.

The configuration of the South Korean coastline and underwater topography play important roles in the effects of waves hitting the beaches. The entire east coast is exposed to rough seas when under the influence of easterly winds. In general, moderate (4-7 ft/1.2-2.1 m) surf persists from Pusan to Chongjin; however, when this region is under the influence of easterly winds, the surf becomes heavy (8 ft/2.4 m or higher). Surf 4 ft (1.2 m) or higher is expected 22% of the time along the east coast during the months October through March.

Along the south and west coasts, the harbors are protected by the many small islands, indentations and shoal areas which dissipate the incoming waves. Surf conditions along these coasts range from light (less than 4 ft/1.2 m high) on the south coast to moderate on the southwest and northwest coasts. Occasionally, however, when under the influence of southwesterly and westerly winds, the surf may become heavy in the northern region of the west coast. Surf 4 ft (1.2 m) or higher is expected to occur 9% of the time during April through September.

The frequency of waves 5 ft (1.5 m) and higher with periods less than six seconds ranges from about 20% in the south to about 25% in the north on the east coast, whereas on the west coast about 60% of the waves will have periods less than two seconds with heights less than 2 ft (.6 m).

The seasonal distribution of sea and swell can be summarized as follows:

Winter (Figure 3-33). During winter, in keeping with the steadiness of the monsoon, sea and swell are predominantly from the northern quadrant. High seas (greater than 12 ft/3.6 m) occur with a frequency of about 4% throughout all the area. High swell (greater than 12 ft/3.6 m) is observed in all portions south of the 38th Parallel, but it is most frequent in the southern Yellow Sea where long fetches and favorable winds result in a buildup to greater heights. Calm seas are comparatively rare with only the most sheltered waters showing more than 7% occurrence.

Spring (Figure 3-34). By May, when the northerly monsoon is changing to southerly, sea and swell are quite variable. While southerly seas have become slightly dominant off the east coast, the northerly component of the winter monsoon continues to prevail in the nearshore waters of western South Korea; here, a large portion of seas continue to come from the northern quadrant. In the northern part of the Sea of Japan, southeast swell predominates; but in the southeastern part of the area, northeast is the predominant direction and south is secondary. Elsewhere over the area, swell directions are extremely variable with the southerly component only slightly more prominent. Spring is the calmest season for South Korean waters, with high sea and swell seldom observed. Seas less than 5 ft (1.5 m) and swell less than 6 ft (1.8 m) are the rule 80-100% of the time during this period.

Summer (Figure 3-35). The circulation over the entire Peninsula is rather weak during summer, and although the winds are variable, the southerly monsoon is the controlling factor. July is the month of strongest southerly flow, and by September, the northerly monsoon begins to predominate once again. Sea directions during summer, although slightly variable, are generally from the south. Swell, not as readily affected by short range wind fluctuations as sea, is more prevalent from the southerly quadrant. Seas greater than 5 ft (1.5 m) occur over the entire area, and seas greater than 12 ft (3.6 m) are observed in the south and open-western parts of the area. High swell is observed over the entire area. The southern part of the area has the highest frequency of high swell as a result of the southerly flow over the long fetches from the East China Sea.

Fall (Figure 3-36). Although somewhat variable, seas are predominately from the northerly quarter and correspond to the autumnal circulation. Similarly, swell during fall occurs most frequently from the northwest through northeast directions. During this season, as in winter, high sea and swell occur frequently. The roughest wave conditions are felt off the exposed east coast. Seas 5 ft (1.5 m) or higher and swell 6 ft (1.8 m) or higher are reported in 20-40% of the observations in Peninsula sea areas.

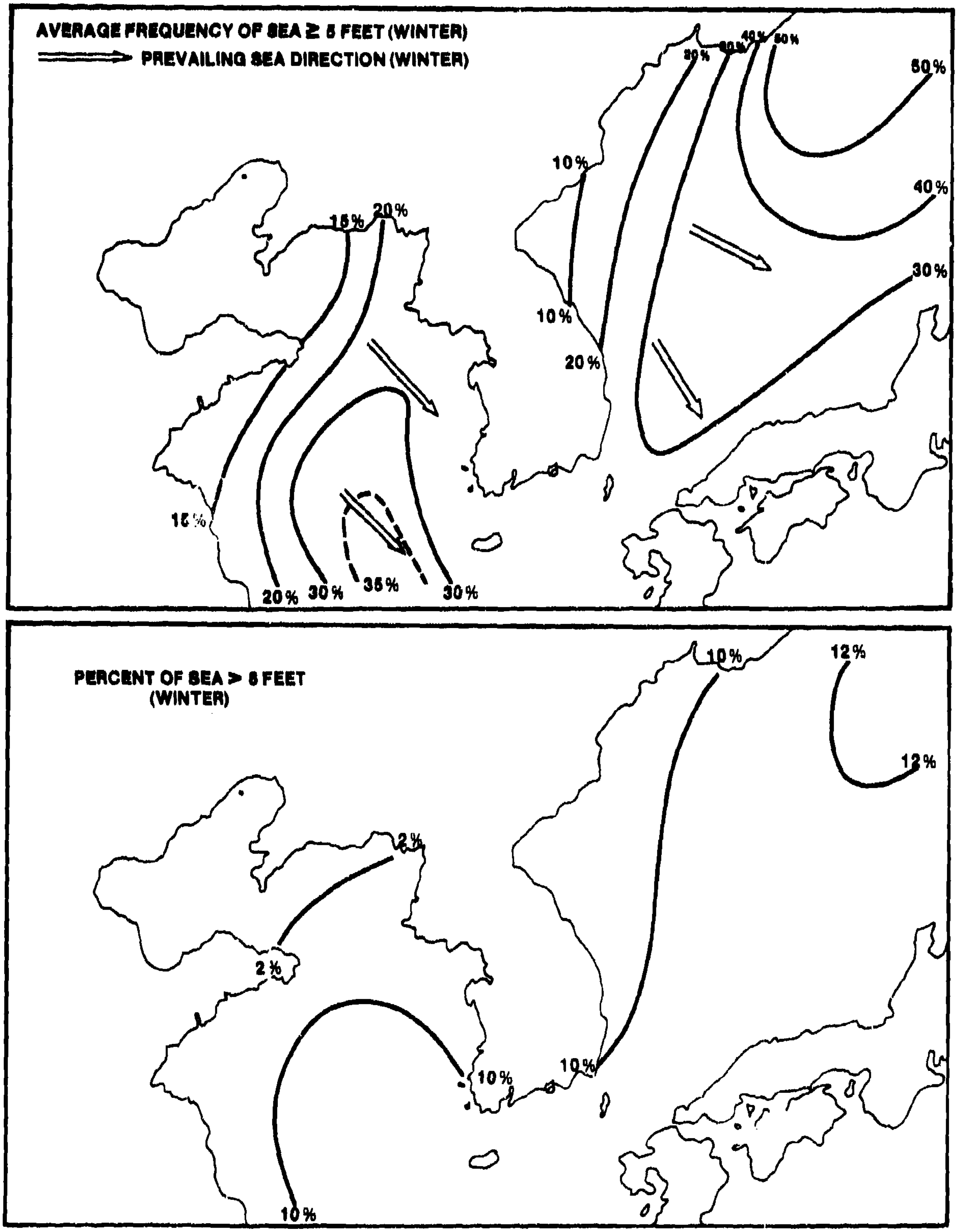
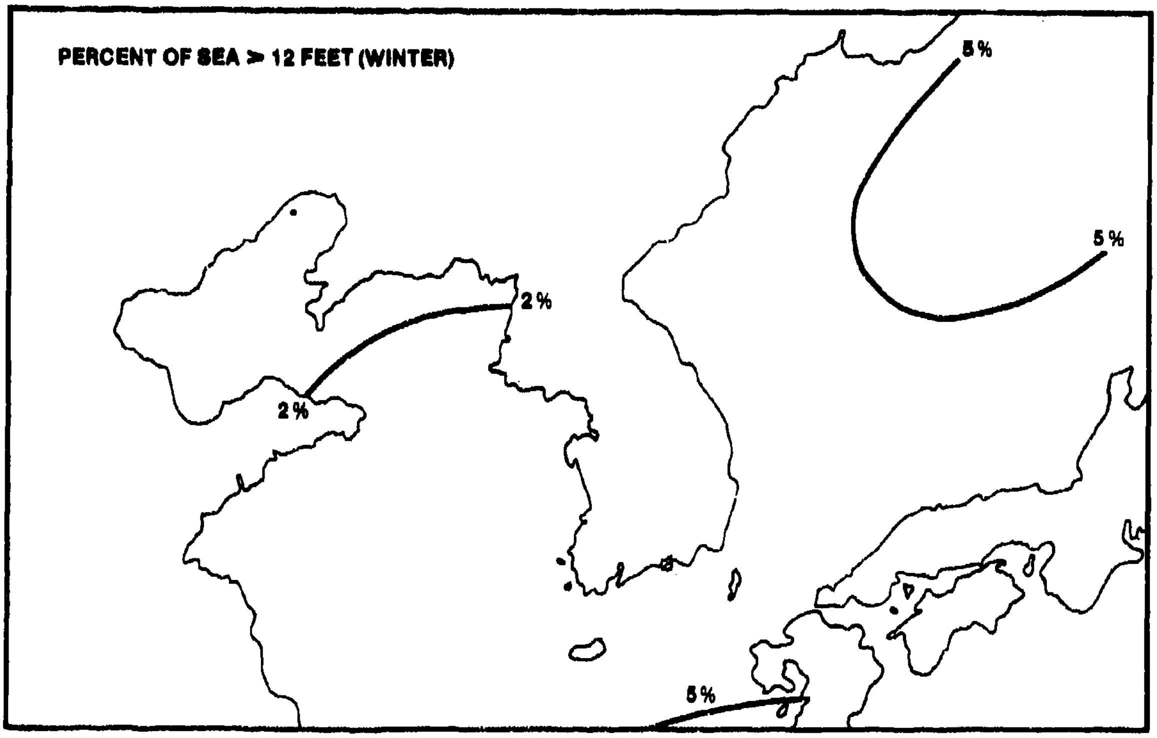


Figure 3-33. Mean sea height data for winter (from 1st Weather Wing, USAF).



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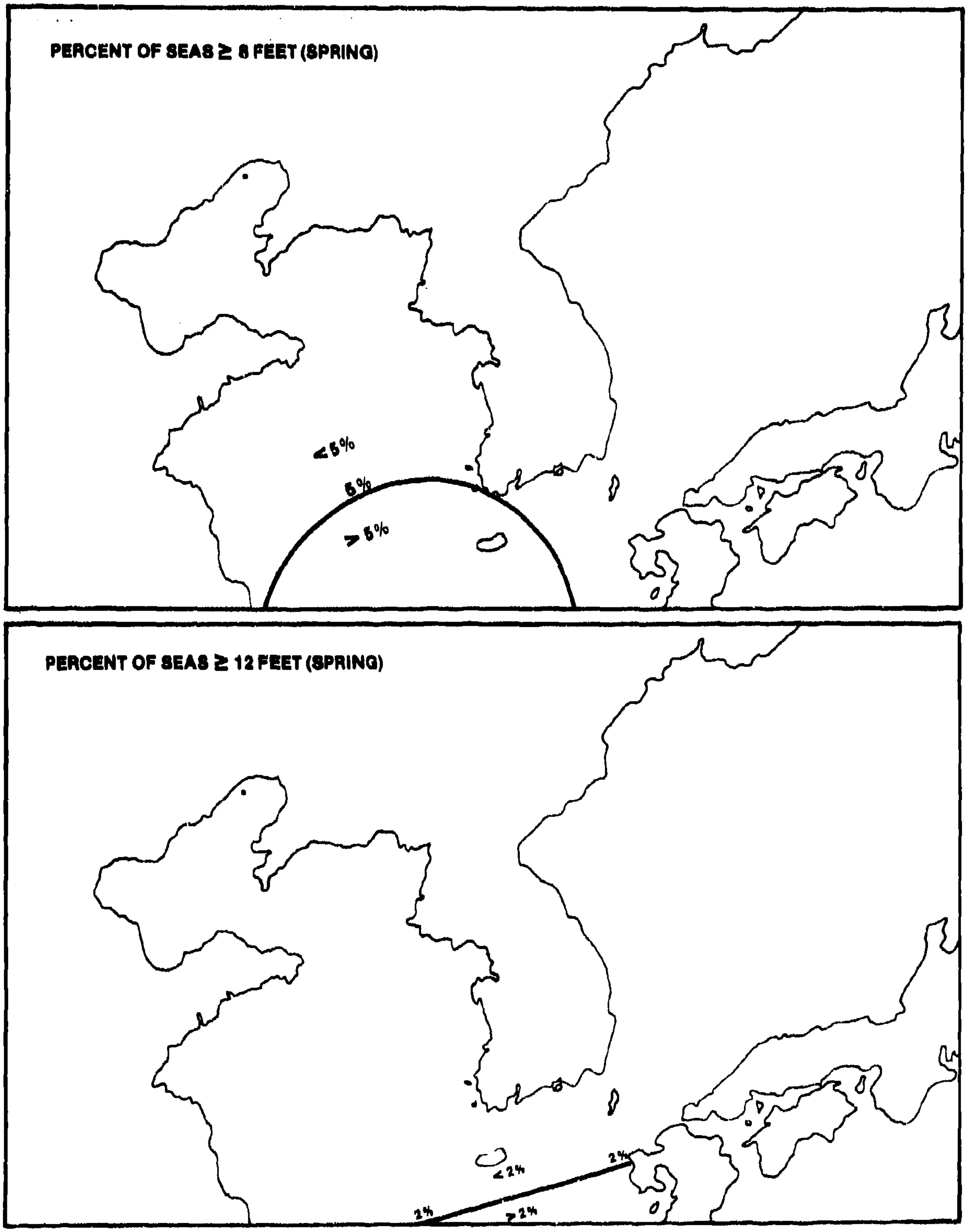


Figure 3-34. Mean sea height data for spring (from 1st Weather Wing, USAF).

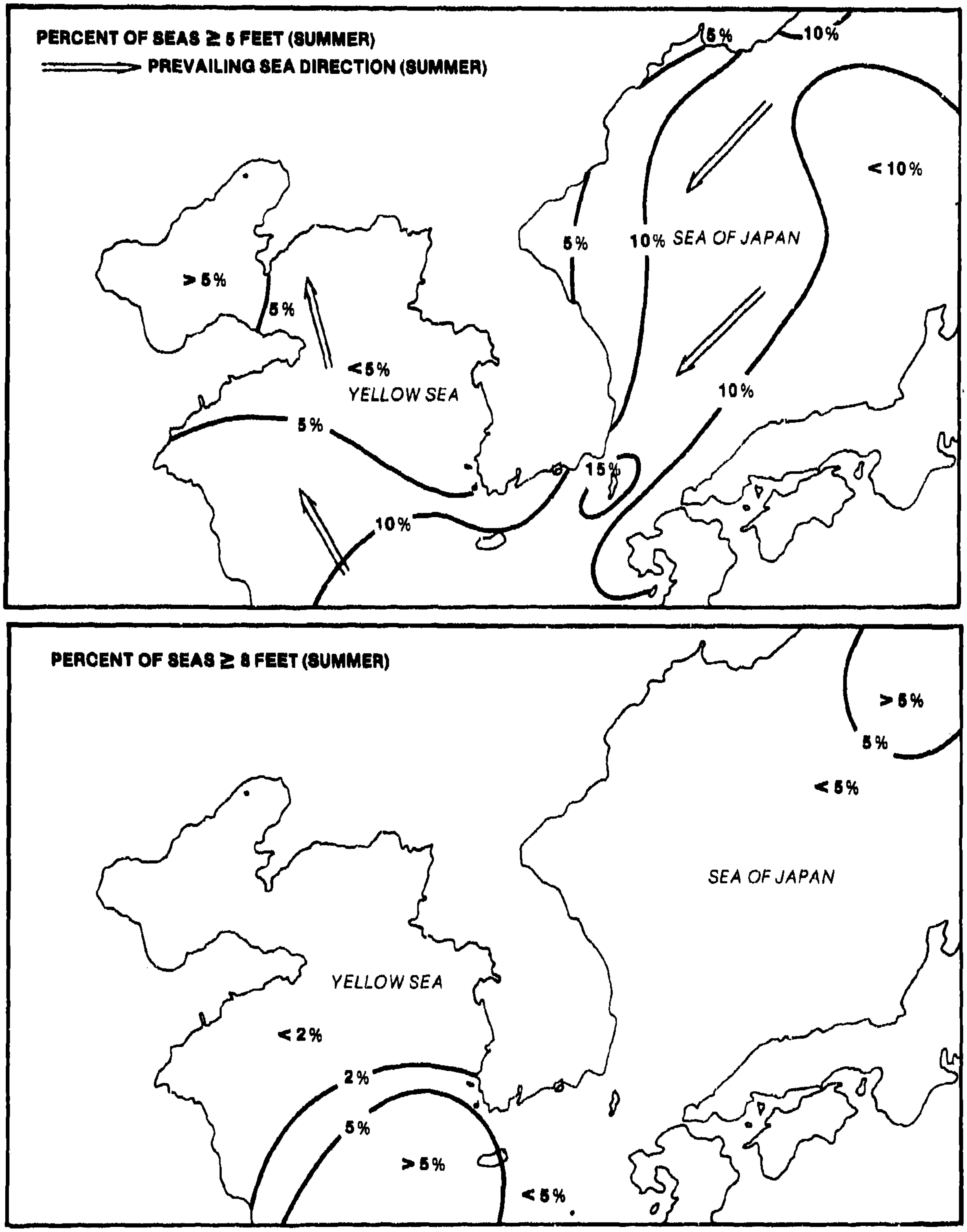


Figure 3-35. Mean sea height data for summer (from 1st Weather Wing, USAF).

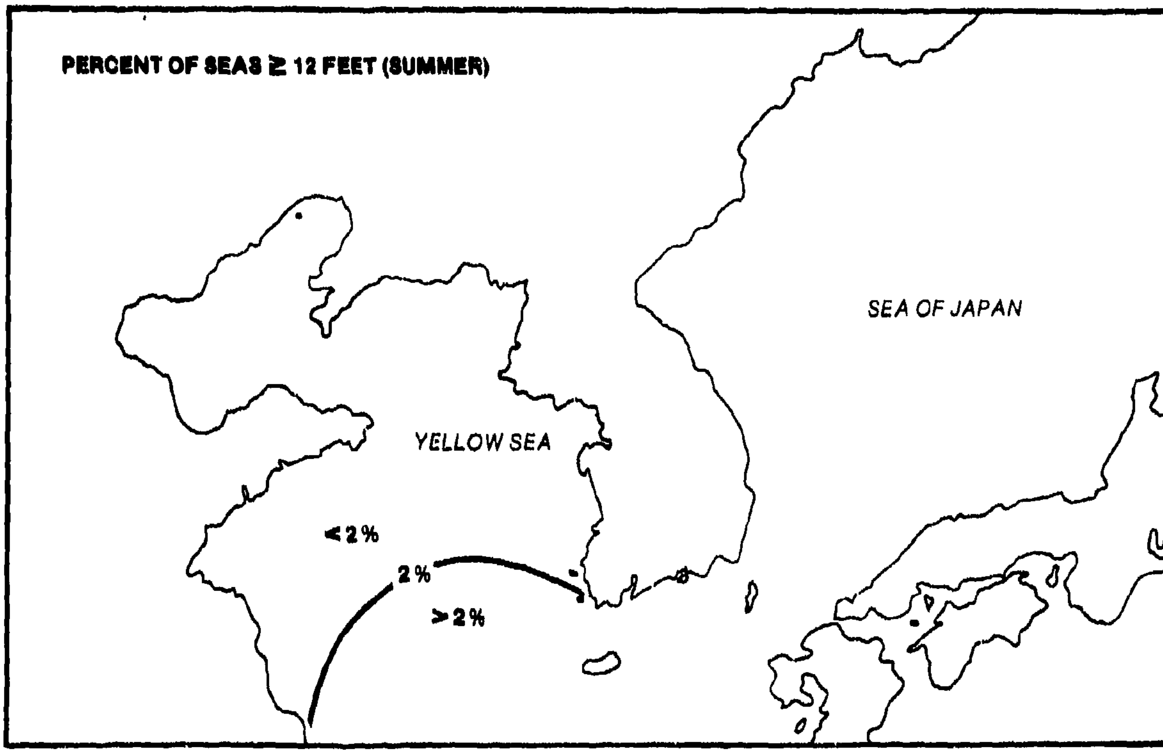
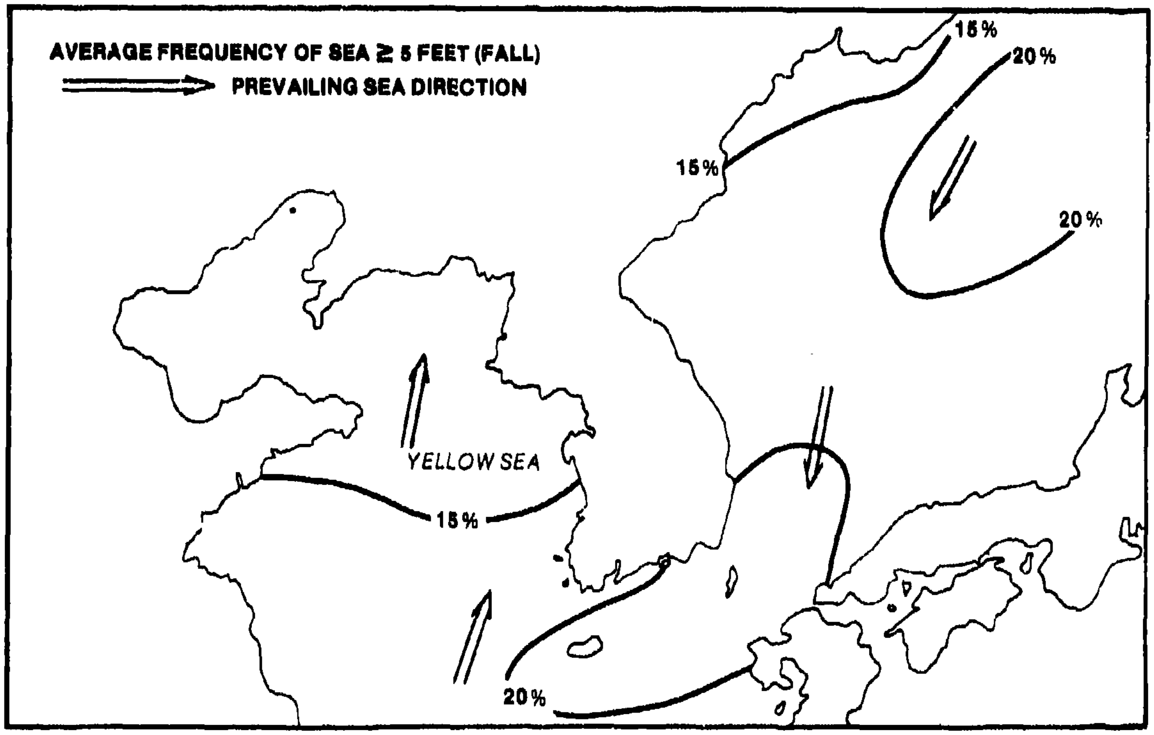


Figure 3-35 continued.



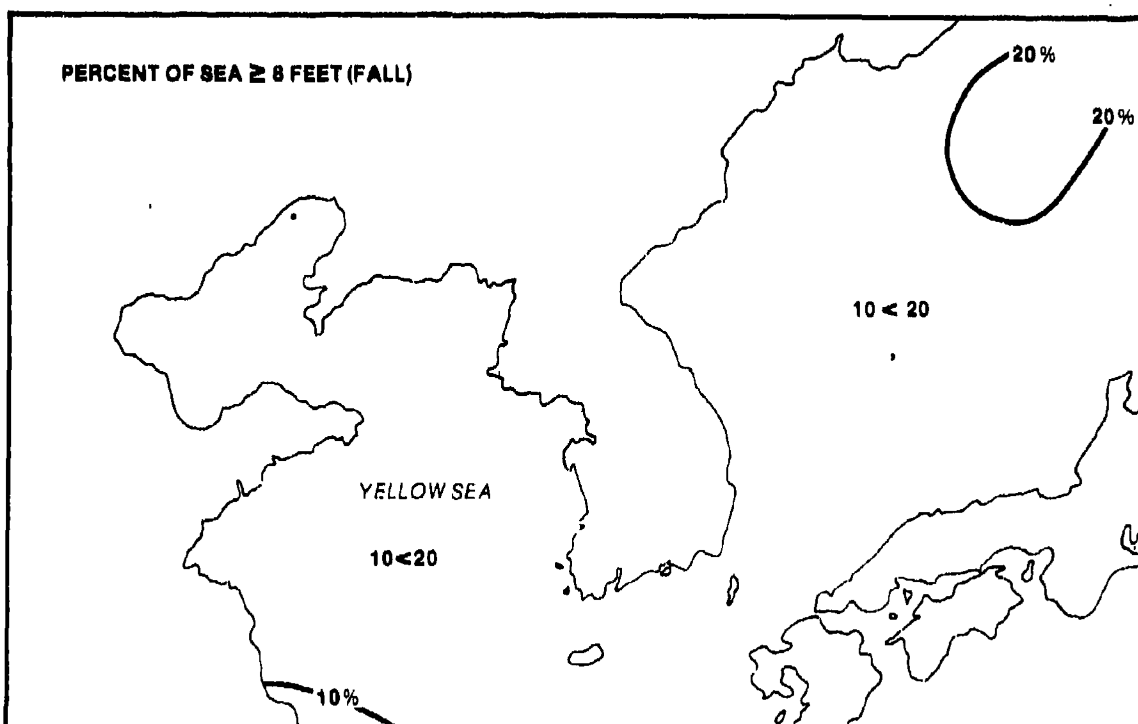


Figure 3-36. Mean sea height data for fall (from 1st Weather Wing, USAF).

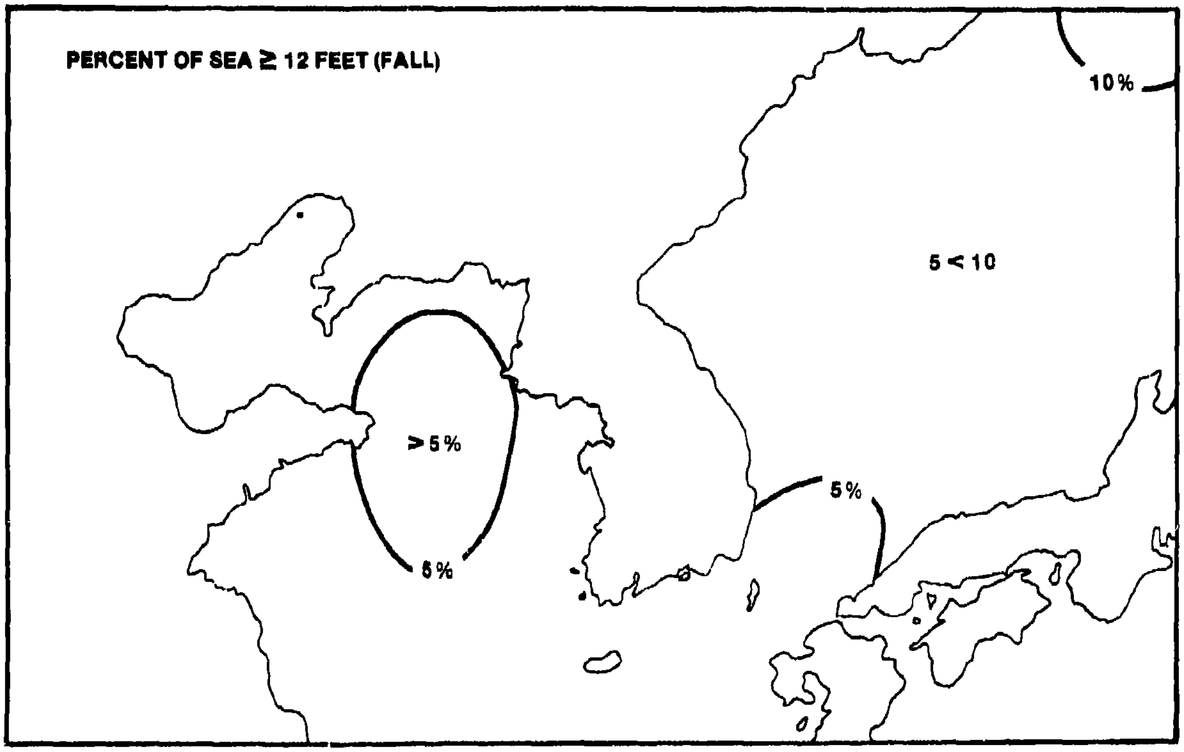


Figure 3-36 continued.

3.4.4 Tidal Data and Tidal Currents

The tides around the coasts of the Korean Peninsula are shown in Figure 3-37. Tides on the east coast are so small as to be negligible. The south coast is characterized by mixed* and semidiurnal tides, the semidiurnal tides occurring in the area between 127°30'E and 129°00'E. Along the west coast, tides are mixed except for the areas between 36°N and 38°N and between 39°N and 40°N, where they are semidiurnal.

Tidal progression along the east coast is in a southward direction with high water occurring nearly simultaneously from the Russian border to 37°N. South of this latitude the progression slows considerably, reaching Pusan in about four hours. The progression is westward along the south coast, while along the west coast it is northward. The tidal range along the east coast is small, with mean ranges varying only a few inches and tropic ranges varying only a foot or less; daily variations in water level from weather causes are often greater than those from astronomical influences.

*Mixed tide -- tide showing mixed characteristics of diurnal and semi-diurnal tides.

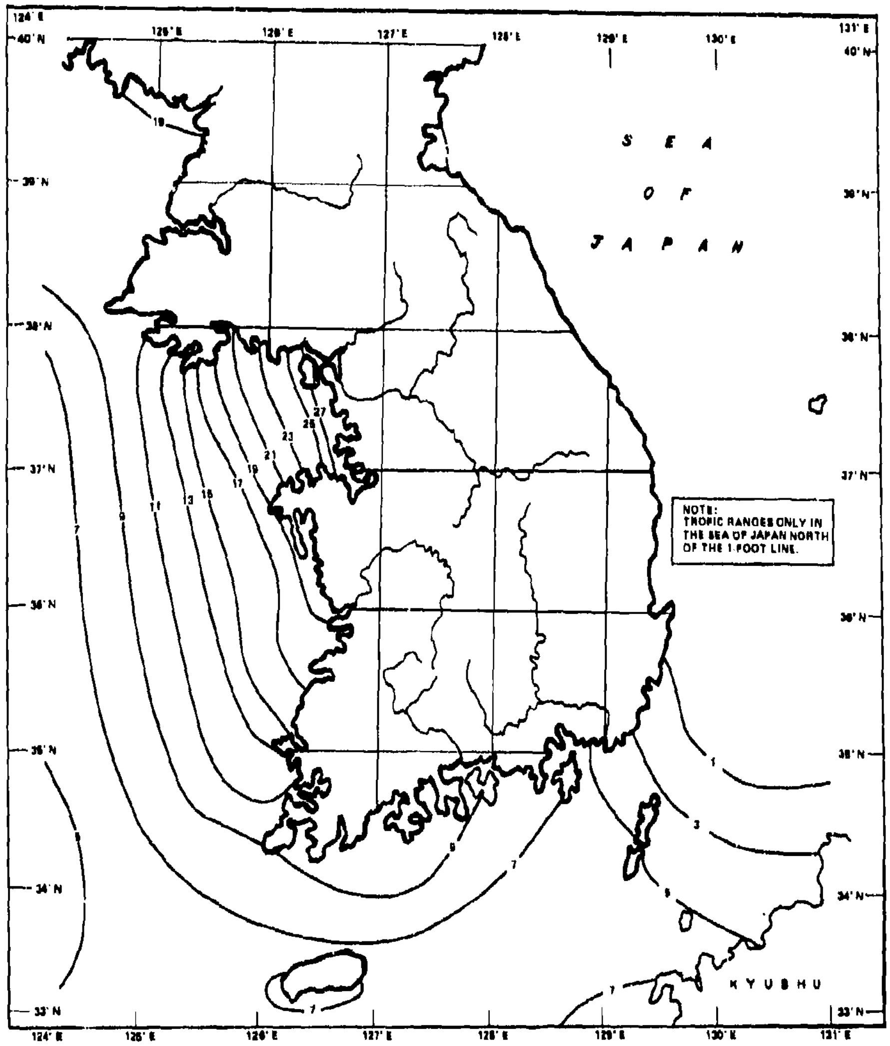


Figure 3-37. Spring and tropic tidal ranges (ft) in sea areas adjacent to the Korean Peninsula. (Note: The tropic range is the average of the larger range that occurs fortnightly at times of maximum north or south lunar declination. In the case of the east coast, such ranges are almost negligible.)

The mean range is 3-8 ft (.9-2.3 m) along the south coast with spring ranges reaching 11.5 ft (3.5 m). Along the west coast and among the offshore islands, the mean range varies 2-21 ft (.6-6.4 m) with a maximum spring range of 32 ft (9.7 m) near Inchon.

Currents are generally very weak along the east coast; close to the shore, they flood to the southwest and ebb to the northeast. Along the south coast, the tidal currents are semidiurnal (two floods and two ebbs each tidal day) and mixed-type tides.

The flood tide generally sets to the west changing to northwest, and north around the southwest tip of the Peninsula. The ebb sets in the reverse direction. Speeds range from 1.5 kt in offshore areas to over 10 kt close inshore between the various islands. Along the west coast, tidal currents are predominantly semidiurnal, flooding to the north and ebbing to the south in offshore areas, and turning east to flood ashore in the bays and estuaries. Maximum flood generally occurs about three hours before high water, and maximum ebb three hours after high water. Slack water occurs at about the time of local high and low water.

3.4.5 Annual Mean Salinities

Detailed information on salinities in the surface layer (down to 400 ft/122 m) can be found in the Department of the Navy North Pacific Ocean Atlas, Naval Oceanographic Office Reference Publication 2, 1976.

3.4.6 Ocean Survival Times

Figure 3-38 illustrates the very short life expectancy of personnel immersed in the cold sea areas around South Korea without protective immersion clothing. The inset in Figure 3-38 is a standard chart of water temperature vs. immersion time, while the main figure shows selected Peninsula locations and expected water temperatures at these points during winter.

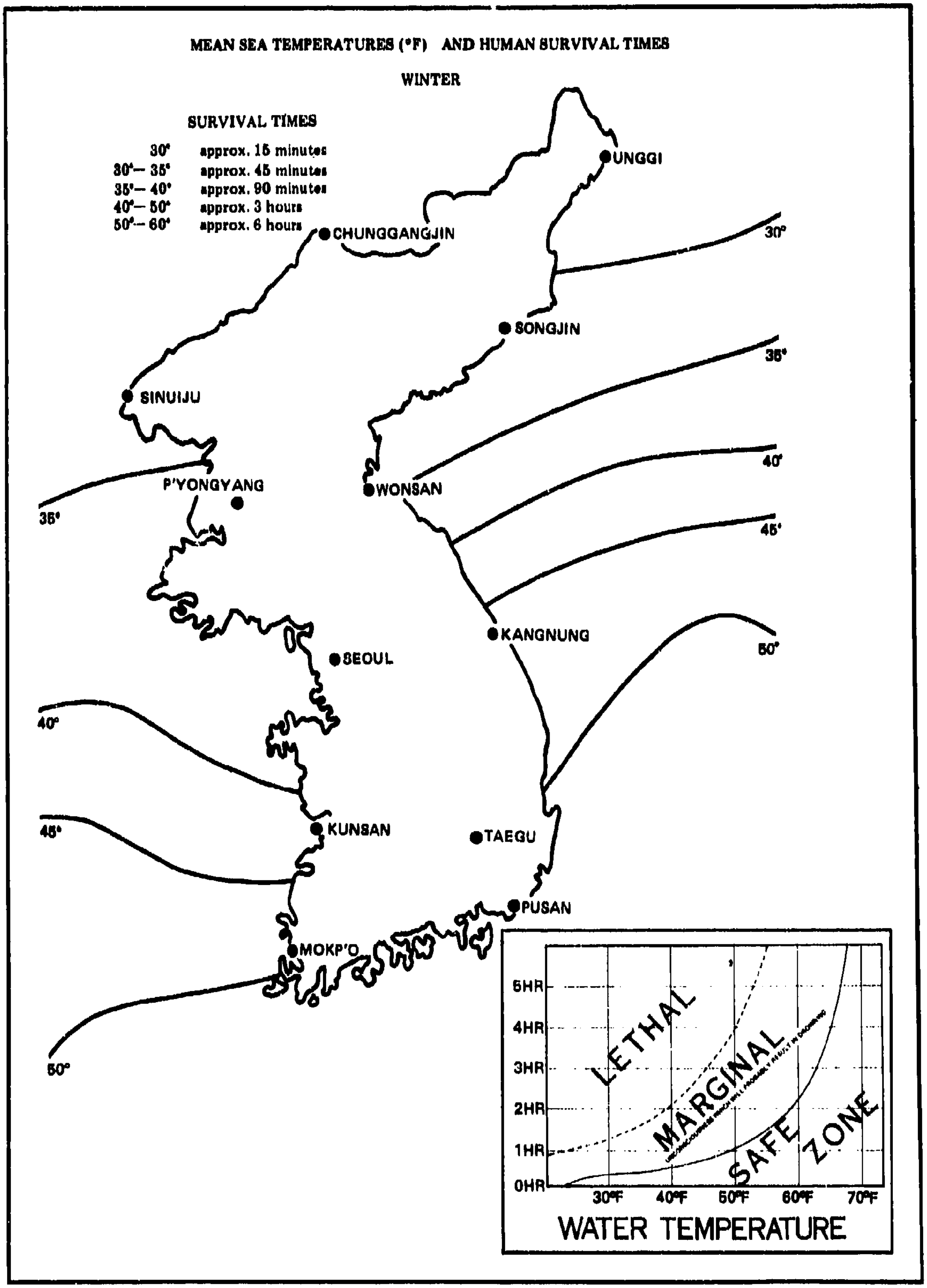


Figure 3-38. Mean sea surface temperatures (°F) and human survival times in winter.

3.4.7 Ambient Ocean Noise (Figures 3-39, 3-40)

The principal sound-producing crustaceans in the Sea of Japan, Korea Strait and Yellow Sea are the snapping (or pistol) shrimp and the spiny lobster (Figure 3-39a).

Shrimp. The small snapping shrimp produces a loud snapping sound with its claws. Colonies of these creatures produce a continuous noise resembling frying fat; the frequency range is 500-20,000 Hz, with principal components at 2000-6000 Hz. This crackle dominates water noise above 2000 Hz and is a strong masker of acoustical signals. There has been no observed seasonal variation in the noise created by these creatures, but a slight diurnal variation has been observed with night levels slightly higher than day.

Shrimp beds are located mainly along the southwestern coast of Japan in the Sea of Japan and the southeastern coast of the Korean Peninsula in the Tsushima Straits area.

Lobsters. Spiny lobsters make a rasping or rattling sound by rubbing their antennae against their shells. The frequency range is 40-9000 Hz, with the greatest intensities occurring at 600 and 800 Hz and in a band 2500-4700 Hz. These crustaceans congregate in groups and can be a major factor in the overall ambient noise level of an area. Spiny lobsters are found in the Tsushima Straits areas along the southeast coast of the Peninsula and along the southwest coast of Japan.

Fish. The principal sound-producing fish in the Sea of Japan are bottom-dwelling coastal types. Fish sounds fall into categories below 1000 Hz; the triggerfish is an exception, emitting sounds in the range 2400-4800 Hz. Two distinct types of sound-producing fish can be identified: the warm water type with strong sonic qualities, and the cold water species with moderate to weak sonic activity. In the Sea of Japan and Korea Strait, sound-producing fish are active year around, with the greatest activity occurring in the spawning months of April through October. Figure 3-39b shows the distribution of sound-producing fish in the Sea of Japan. Representative levels observed at 2 ft (.6 m) from the hydrophone are 34 db for the sculpin, 36 db for the croaker and 24 db for the jack.

Mammals. Whales and seals are the principal sound-producing mammals in the Sea of Japan; their areas of greatest concentration vary with the season and the migratory habits of the species (Figure 3-40). Little information is available on migration patterns around the Peninsula, although the major migration route in winter is thought to be along the east coast of the USSR from the Sea of Okhotsk to Vladivostok. Some gray whales are known to move further south along the east coast of the Korean Peninsula, but designation of such movement as a regular migration route is considered speculative.

Whales are the largest of the sound-producing mammals in these waters, with the bearded seal and harbor seal the only other mammals of any consequence. Predominant species of whales are the fin, killer, gray, white and Minke-Bryde. All the mammals make series of clicks, whistles and moans with frequency ranges varying from 1.5 to 2.5 KHz with maximum sound levels in the range 60-74 db.

Scattering. Data are lacking on the presence of deep-scattering organisms and layers in the Sea of Japan, but a non-migrating sound-scattering level is known to exist during the month of April and the period June through November. The upper levels of this layer vary from 48 ft (15 m) near the Asian mainland to 191 ft (58 m) off the east coast of the Peninsula. The depths of the lower levels range from 168 ft (51 m) near the Asian mainland to 246 ft (75 m) near the west coast of Honshu. The average depth of the upper level of the layer is 110 ft (33 m) and the lower average is 190 ft (58 m).

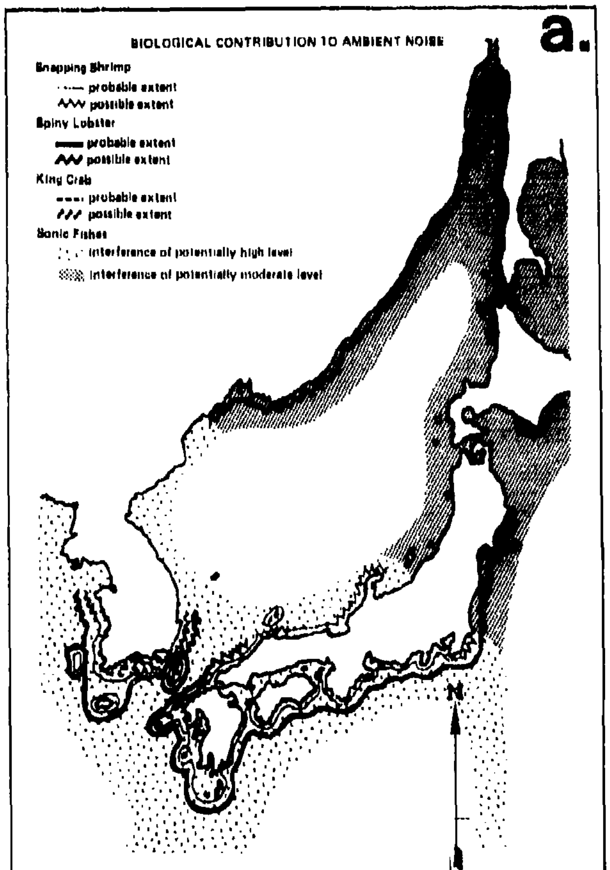
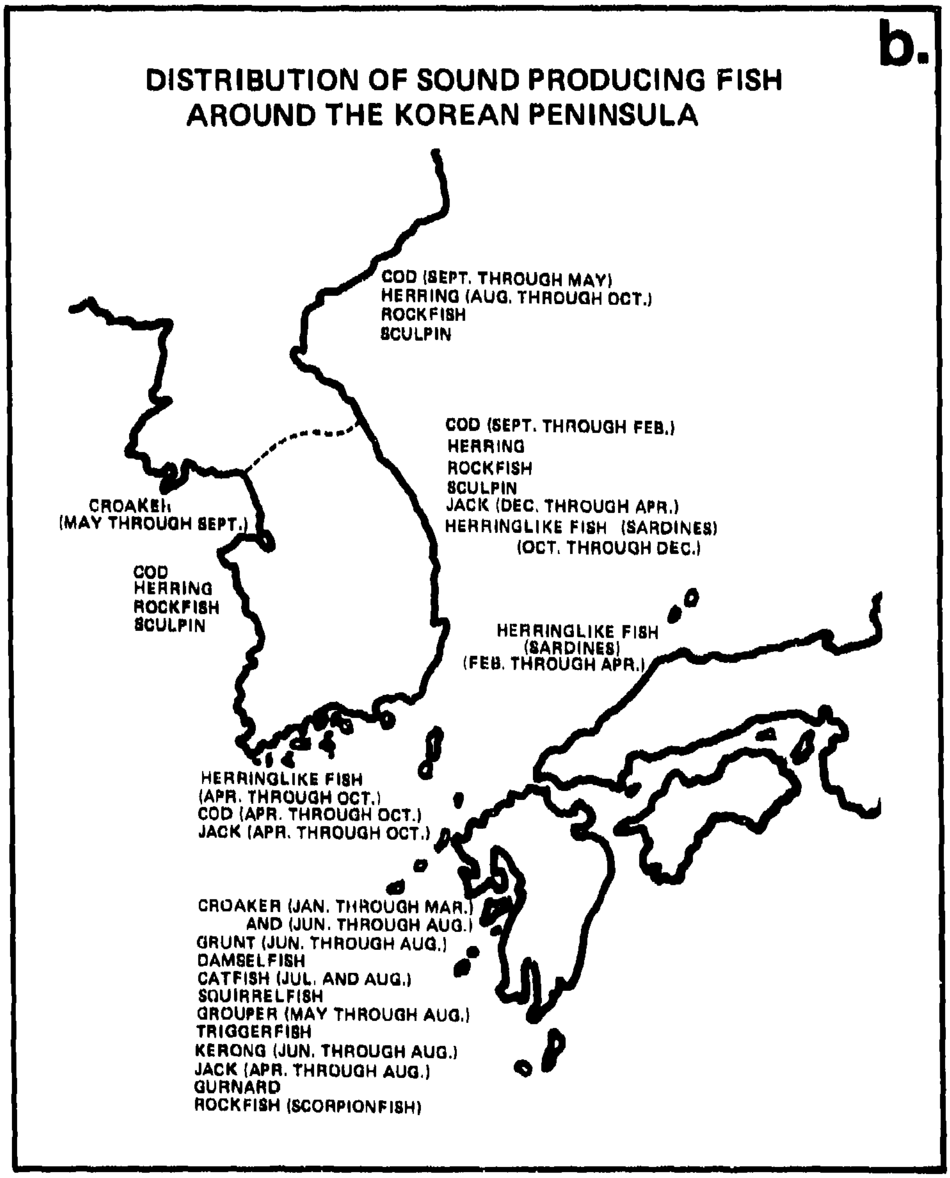


Figure 3-39. Sound-producing creatures in Korean Peninsula waters: (a) biological contribution to ambient noise; (b) distribution of sound-producing fish.



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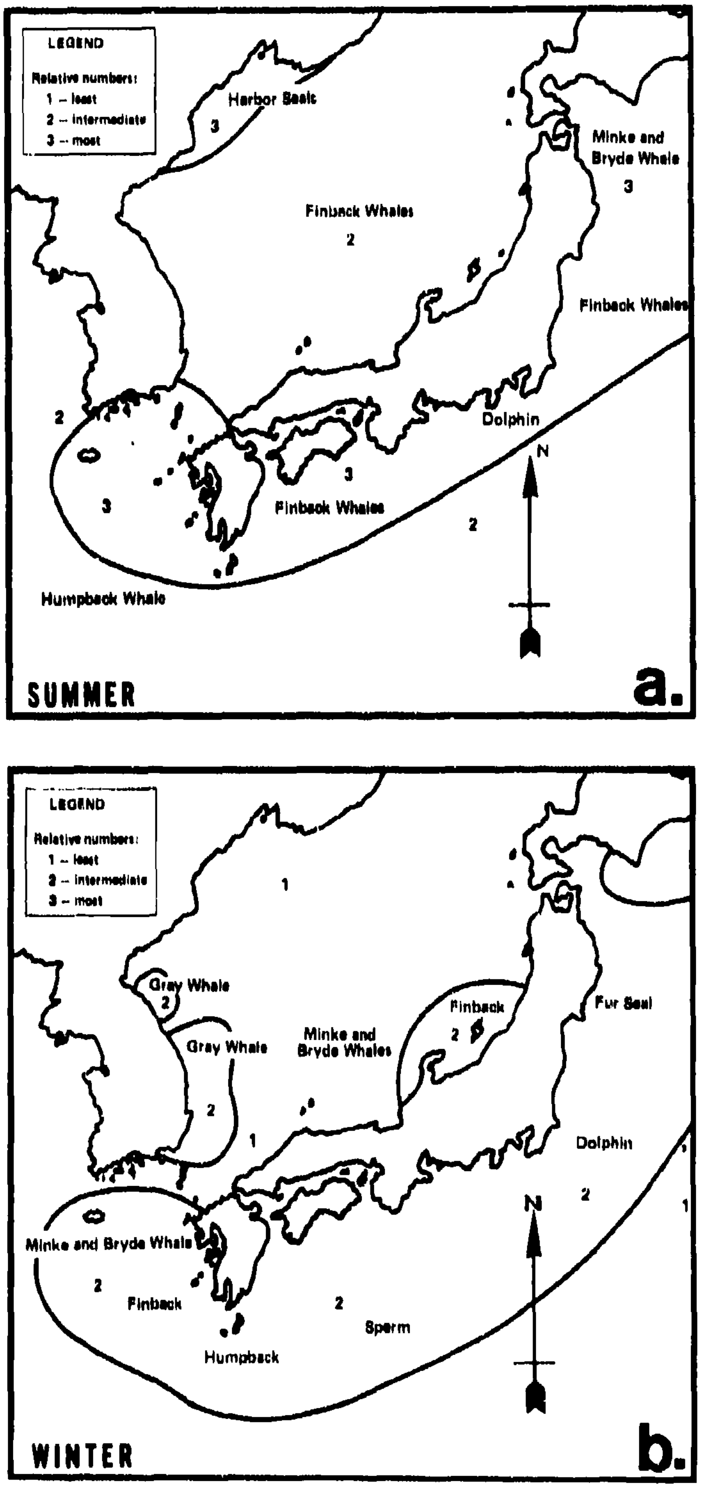


Figure 3-40. Distribution of marine mammals in the sea areas around the Korean Peninsula.

SECTION 4

CONTENTS

4. WEATHER SYSTEMS AND FORECAST GUIDANCE

4.1 INTRODUCTION

This section describes specific weather phenomena that occur within the larger climatological framework of the Korean area; these discussions are intended primarily for the operational meteorologist. Mid-latitude climatology as well as seasonal progressions relative to warming/cooling of the Eurasian land mass, were discussed in Section 3.

The tracking and forecasting of any weather system moving over the Korean area is complicated by the rugged terrain barriers. Shallow air outbreaks move erratically, while deep systems move more smoothly. Surface fronts may move aloft in passing over major peaks and then become indistinct. Segments of fronts are often slowed down or completely blocked by terrain barriers. The veering of the low level winds which normally accompany frontal passages may be retarded for several hours at stations in valleys with northeast-southwest orientation, a phenomenon that is often misinterpreted as an indication of frontal deceleration or wave development.

Because few surface reporting stations' data are truly representative, 850 mb data are more significant in analyzing weather situations. The encircling mountain wall on the Asian continent (and to seaward through the adjacent island chains) influences the characteristics and trajectory of all pressure systems moving across the area. Travelling disturbances in the westerlies alter their character significantly as they move off the Asian continent in winter, due to the very rapid acquisition of heat and moisture from below; for this reason, extrapolative forecast techniques are especially weak.

Weather types are difficult to use as forecast tools since they are often difficult to discover during their early stages of development; also, variations of the same type often produce totally different weather effects. Weather types are useful, however, in fixing the broad-scale synoptic pattern and relating smaller scale features to the larger overview. For example, they will often give a clue to the persistence or repetition of those small scale features that depend on persistence or change in the large scale pattern. (Seven weather types associated with the East Asian/Northwestern Pacific area are discussed in Appendix A.)

It is extremely difficult to forecast weather in the Korean area, other than for winter. Data are often misleading and only careful attention to the most minute changes can avert substantial failure on even short range forecasts.

It is also difficult to formulate any set rules given the quantity and quality of data generally available. In a few cases, rules for winter can be established and applied successfully; during this season, weather systems follow a more definite pattern -- highs are more intense, lows are deeper and fronts are more pronounced -- so empirical rules become more pertinent.

4.2 FRONTAL SYSTEMS

The majority of cold fronts that approach the east Asian coast are the result of old occluded fronts originating in Europe. Waves frequently develop on these fronts during their southerly movement toward the Korean Peninsula. To assist in the prediction of intensity and movement of such wave developments over the Yellow, East China, and Japan Seas, it is necessary to have some understanding of their history and associated frontal systems.

These cold fronts move from the Asian continent, avoiding the Tibetan plateau, and follow a southeastward and easterly movement toward the Korean Peninsula and Japan. They frequently cause very severe invasions of cold air from the areas noted for the lowest winter temperatures on record throughout the world. They can be divided into three basic types, with tracks as shown in Figure 4-1.

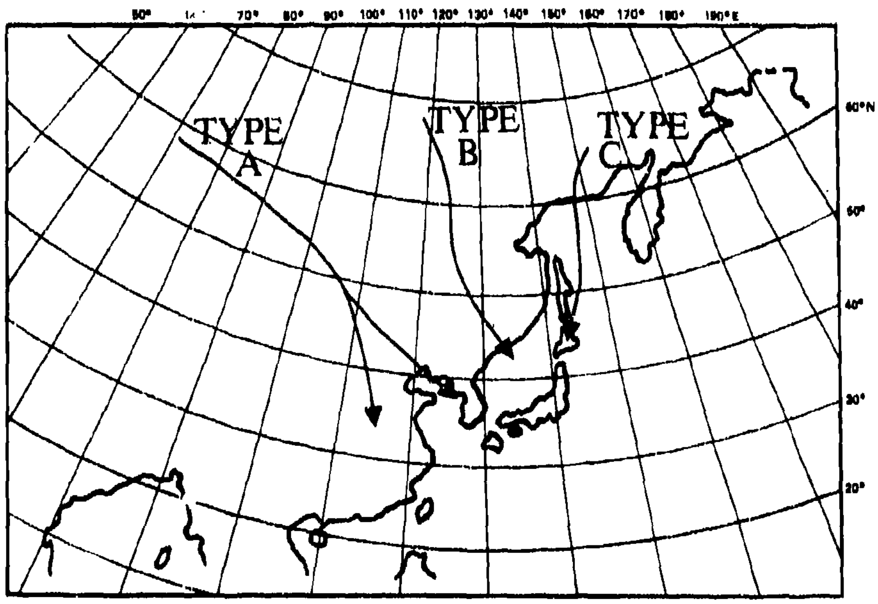


Figure 4-1. Tracks of cold frontal systems across Asia: Types A, B, C.

4.2.1 Types of Cold Fronts

The three types of cold fronts, defined on the basis of origin and movement, are:

(1) Type A (western) -- originates on the shores of the Arctic Ocean in western Siberia.

(2) Type B (central) -- originates in eastern Siberia between longitude 100° to 140°E and about latitude 55° to 70°N.

(3) Type C (eastern) -- forms near longitude 150°E/ latitude 60°N and travels toward the south-southwest along the east Asian coast and towards the Korean Peninsula.

Type A cold fronts occur most frequently throughout the year and often branch in northern Mongolia at about 47°N, 105°E. One portion travels toward the east-southeast into northern China, reaching the coast at about 40°N. The other portion, which occurs less frequently, travels south-southeast as far south as southeast Asia. Cold fronts of Type A are quite shallow and rarely cause severe falls in temperatures over the Korean area. Cyclogenesis along these fronts over the Shantung Peninsula creates widespread frontal weather. This type may cover the greater part of East Asia during January to February, at which time the high pressure center behind the fronts will often reach a central pressure of 1065 mb.

Type B cold fronts also occur frequently and are especially severe in northern and central China, Manchuria, Mongolia, the Korean Peninsula and Japan. They are considerably deeper than those of Type A, and are associated with very dry air and very pronounced reductions in temperatures. Type B is most frequently observed in midwinter.

Type C frontal systems, although not occurring as frequently as Types A and B, produce considerably more weather because of their marine trajectory. Heavy rain, snow and low overcast occur, particularly along the eastern coast of the Korean Peninsula, with overcast to broken skies in the Yellow Sea. Low centers along this front at any time of the year may develop very rapidly and cause extremely high winds. Type C is most frequent during spring and early summer, with a secondary maximum of frequency in November.

Relatively strong meridional flow at 500 mb, with a long wave position over the Korean Peninsula, will produce Type A outbreaks. Very strong meridional flow, or a block north of Mongolia, and a long wave over Japan will generate Type B outbreaks. A well established, nearly stationary low at 500 mb over Kamchatka, or just to the east, with a high centered northeast of Asia, will produce Type C outbreaks. The flow pattern at 500 to 200 mb determines the direction the cold air will follow. The availability of moisture determines the weather in terms of precipitation and clouds.

An indication of frequencies of cold front occurrences, based on 1951-52 records, are shown in Table 4-1; total for the year is 56.8 occurrences. The maximum number of cold fronts occur from November through April and May; there is a sharp decline in June, and a marked increase in November.

Table 4-1. Frequency of all Far East cold front occurrences (1951-52 records).

Jan -- 4.0	May -- 5.0	Sep -- 3.0
Feb -- 6.8	Jun -- 1.0	Oct -- 3.0
Mar -- 5.0	Jul -- 2.0	Nov -- 9.0
Apr -- 6.0	Aug -- 2.0	Dec -- 10.0

The first series of significant cold fronts, usually Type A or B, occur with great regularity between the latter part of October and early November; the second, more severe series about early December; and the third, a very severe cold wave outbreak, in the latter part of January or early February.

Because speeds of advance of these cold waves are influenced by topography, forecasting is very difficult. They generally average 25 kt, with speed maxima of 45-60 kt down mountain slopes in winter, to less than 9 kt in summer, fall and spring when approaching the mountain ranges.

Although the vertical thickness of cold waves has not been determined, it is believed that they do not extend to much more than 6500 ft (1981 m) and may possibly reach 10,000 ft (3048 m) on rare occasions during the more severe cold outbreaks. These estimates have been made mostly from observed movements of cold waves over the mountain ranges. Increases in temperature have been noted occasionally at mountain tops with an appreciable drop at the lower levels. It can also be shown that many cold waves remain stagnant in front of a range while others move freely over, thus indicating to some measure the variability in the depth of the surging cold air.

4.2.2 Slow Moving Cold Fronts and Associated Depressions

The mountains of North Korea, 5000-7000 ft (1524-2134 m) high, will affect the majority of cold fronts, especially the slow moving ones. As a general rule, the slow fronts will appear in spring, summer and fall with an average speed of 12-16 kt. Ahead of the front, 850 mb level winds will generally be west to southwest 10-15 kt, veering to west or northwest 15-30 kt after passage. Slow fronts may undergo cyclogenesis in this area on the windward side of the mountains in central Manchuria (Figure 4-2).

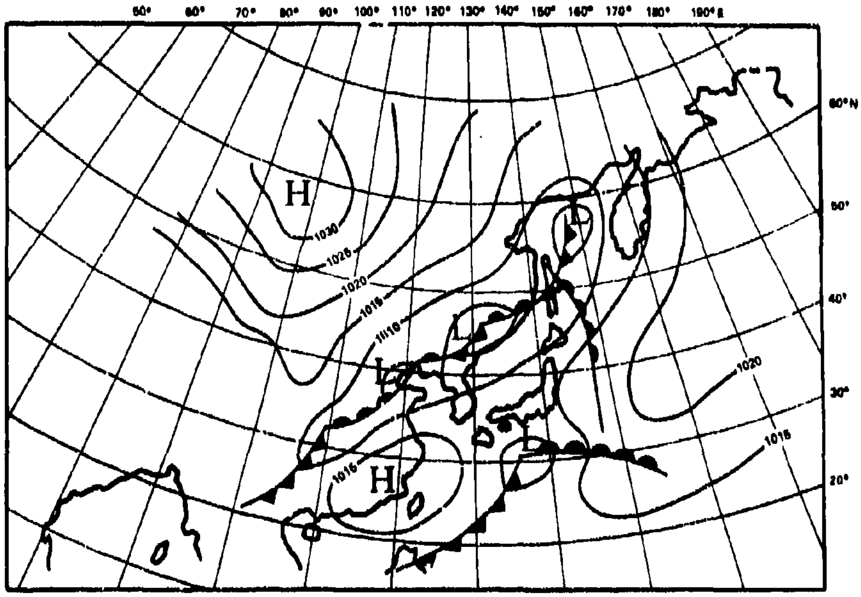


Figure 4-2. Series of waves associated with a slow moving front over the Korean Peninsula in a typical situation during the spring and fall seasons.

Cold, stable air will generally continue along the path of least resistance and the front will likely continue south and approach the Shantung Peninsula. As it does, it is affected by the Shantung Hills, 3000 ft (914 m) in height, and cyclogenesis is again set in motion. If, in this instance, the semipermanent high appears to be moving southeasterly with its elongated axis oriented northwest-southeast, the cold front is likely to continue into the Yangtze River valley where a tertiary wave may form.

With such a synoptic situation involving three lows, no rapid movement or development should be expected until the line of discontinuity becomes more unstable. This will not occur until energy is induced into the system, and no area is more apt to encourage this than the Sea of Japan/Yellow Sea or the East China Sea. At such a time, a low in the Sea of Japan (formerly over the Shantung Peninsula) and a low in the East China Sea (formerly in the Yangtze River valley) will deepen and move east-northeast. The low in Manchuria will continue on a northeast or easterly course with its intensity remaining the same or possibly degenerating. The Shantung low will be of major importance to the Korean area in such a case, so a brief description of its weather conditions is given.

Preceding the frontal outbreak, warm front type clouds will exist on the west coast as much as 36 hours in advance, with medium-level overcast skies 12 to 24 hours ahead of the front. This time sequence usually holds true only for winter. The cold sequence may appear during summer and transitional months, but the time element is very unpredictable. Considerable fog will occur along

the northern part of the coast, especially in spring, summer and fall. Winds will be variable in intensity from the south 5-20 kt, depending on the position and intensity of the high pressure area east of the Korean Peninsula and the low system to the west. Surface winds will shift to northwest 20-30 kt after passage of the front.

The east coast will also have warm front type clouds preceding a slow moving cold front and will always experience lighter southerly winds than the west coast (except for certain areas where foehn winds occur; see Para. 3.2.2). The warm front clouds will prevail, but they will not be as dense as along the west coast until approximately eight hours prior to the arrival of the front; then the ceiling will rapidly lower and scattered rain showers or snow will appear. Behind the front, surface winds will veer to westerly instead of northwesterly, increasing with the same intensity as on the west coast. The time of cloud sequence is quite regular in winter, but very changeable during the warmer months.

If a low overcast continues three to nine hours after a frontal passage on either coast, the forecaster can expect either an approaching secondary low (Figure 4-3a) to exist to the west over the Hwang Ho (Yellow) River area or an approaching secondary front (Figure 4-3b). However, if the skies become broken to scattered soon after a frontal passage, clear skies should be forecast for the next 24 hours.

With a secondary low over the Hwang Ho Valley and the frontal system over central North Korea, surface winds will be generally light and variable along the east and west coasts, with weather conditions dependent on the severity of the low to the west. Flying weather will be marginal in the coastal areas and instrument weather will prevail in the mountains. If surface winds become light westerly behind a front and no large increase in pressure is observed, a secondary cold front or wave can be expected in 12 to 24 hours.

4.2.3 Fast Moving Cold Fronts

The majority of cold fronts in winter are fast moving with average speeds of 25 to 35 kt. These fronts extend to higher levels than the fronts in spring, summer and fall and are temporarily held up in their southward movement by the North Korean mountains; the layer above 5000-7000 ft (1524-2134 m) will pass off as an upper cold front at Wonsan. Then, within 75-125 mi (120-200 km) of the coast, these fronts may be picked up at the surface again and at times may be very severe. Surface winds preceding the front will be dependent on whether or not a depression develops on the leeward side of the Peninsula. Very often, surface winds are west to southwest 10-20 kt preceding the front, veering to west or northwest 25-35 kt about three to six hours after the upper front's passage.

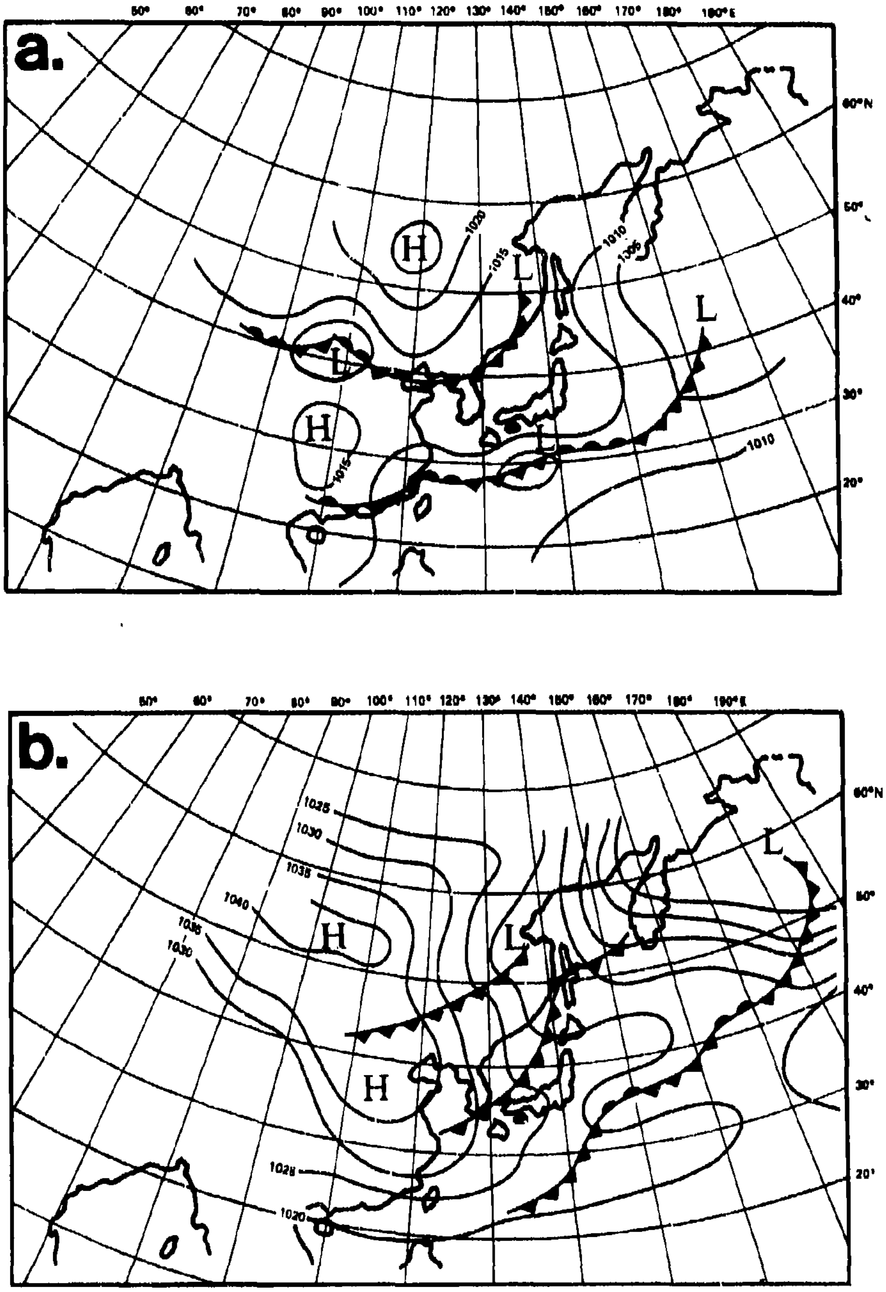


Figure 4-3. Approaching system/front: (a) approaching secondary or trailing low pressure system and (b) approaching secondary cold front.

Any precipitation will normally last from one to three hours with ceilings 500 ft (152 m) and at times 100 ft (30.4 m) and below in showers.

On the west coast, the cold fronts move along the surface and as a result, considerable low stratocumulus clouds develop with bases at 2000 ft (609 m) lowering to 1000 ft (304 m) in snow or rain showers. A very definite wind veer from southwest 20-30 kt to northwest 30-40 kt accompanies the cold front. Across the Peninsula, high and middle clouds appear ahead of the front.

Preceding such outbreaks, pressure will drop and a rise in temperature will be felt 250 mi (402 km) ahead of the front. Rates of pressure fall and temperature increase are reliable clues to the intensity and movement of fronts.

The only stations reporting representative wind directions are those on the west coast. Pressures and weather phenomena are nearly always representative, throughout. For example, at Pohang and Kangnung on the east coast, winds will be from the southwest preceding a front and after passage, will remain southwesterly, but with increased strength.

Fast moving fronts are particularly conservative in their weather, especially in winter; rain showers accompany the fronts until November, and snow showers come in December, January and February. They are also preceded by a light shield of cirrus, becoming altostratus overcast at 8000 ft (2438 m) and then lowering during the period of frontal passage. The cirrus is observed about 36 hours prior to the frontal passages.

Frequently, if strong winds 30-40 kt occur for 24 hours after a cold frontal passage and then the winds suddenly drop to about 10 kt, the forecaster can look for a trough development over the central part of the Peninsula and a "bubble high" to form over the Sea of Japan. Wind flow will become cyclonic at the surface and upper levels, producing widespread weather and slow clearance.

During the summer months, the fronts are less significant and cause only slight disturbances. If the wind at Vladivostok during summer becomes south from the surface to the 700 mb level, a cold front will generally move into North Korea from the northwest. If this wind is greater than 30 kt, the front will move across the Yalu River within 18 to 24 hours. These fronts normally do not move much farther south than 38°N and, in contrast to winter frontal situations, little weather accompanies them.

4.3 EXTRATROPICAL CYCLONES

As is the case with frontal types, the movement of cyclones (and consequently their typing) is a function of the upper air pattern and largely a reflection of the long wave trough position at 500 mb.

Low pressure areas may be classified overall as either old cyclones originating in Eurasia, moving into East Asia and thence easterly/southeasterly toward the Korean Peninsula, or as new cyclones. They are classified together in trajectories and areas of origin.

Table 4-2. Distribution of extratropical Asian disturbances by type (10 yr period).

Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
I	1.4	0.7	1.6	2.7	2.4	2.1	0.8	0.5	0.6	1.7	2.6	1.0	18.1
II	1.0	2.1	3.0	2.0	1.8	2.3	2.7	1.0	1.0	2.0	1.1	1.3	21.3
III	0.3	0.2	0.4	1.1	1.0	0.5	0.1	0.0	0.0	0.6	0.5	0.5	5.2
IV	0.6	0.7	0.7	0.8	0.7	1.1	0.8	0.3	0.7	0.6	0.9	0.7	8.5
V	3.6	3.6	3.4	3.3	3.8	1.8	0.7	0.3	0.4	0.8	1.9	2.7	26.3
VI	0.4	0.8	0.2	0.6	0.2	0.0	0.0	0.4	0.7	0.5	0.5	0.4	4.7
Avg	7.3	8.1	9.3	10.5	9.9	7.8	5.1	2.5	3.4	6.2	7.4	6.6	84.1

The types of disturbances listed in Table 4-2 are characterized as follows:

Lake Baikal, Type I. These cyclones occur throughout the year with a maximum frequency in spring. Their path is parabolic and they travel from Lake Baikal into Mongolia and Manchuria, thence recurving over the Sea of Japan. Their average speed is about 23 kt and they can be traced very often from lows that have originated in central Europe and Scandinavia and moved eastward in association with occluded frontal systems. Generally the occluded section of the frontal system breaks off at the warm and cold front apex and a new independent low emerges.

South Mongolia, Type II. These are the most common cyclones, occurring in all seasons and moving at an average speed of 20 kt. They follow a path through the northernmost part of China, across the Korean Peninsula and Hokkaido, Japan.

Hwang Ho, Type III. These originate primarily in spring with a mean speed of 18 kt, traveling from the Hwang Ho River area in China southeast to southern Japan.

Central Basin, Type IV. These infrequent cyclones occur primarily in summer and fall and move across South Korea with a mean speed of 21 kt.

Yangtse, Type V. These are the most rapid cyclones, averaging 24 kt. They occur primarily during winter and spring, originating over the Yangtze River, then moving toward the East China Sea and then northeasterly off the southern coast of Japan.

Manchurian, Type VI. These develop over the northern border of Manchuria and move into Sakahlin and the Sea of Okhotsk, primarily in fall and spring.

Figure 4-4 shows the tracks of these six types of primary lows.

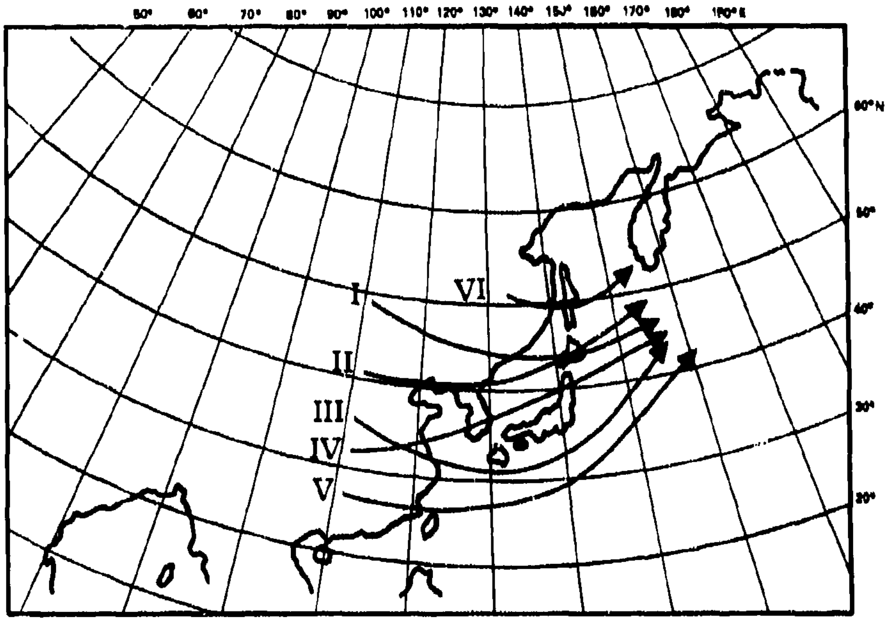


Figure 4-4. Tracks of primary lows, types I-VI.

4.4 CYCLOGENESIS

The upper flow off the east coast of Asia is almost always generally favorable for cyclogenesis during the winter season; given a favorable surface flow, cyclogenesis will inevitably ensue.

The synoptic pattern that most often produces this cyclogenesis is marked by a "bubble high" breaking off from the continental anticyclone. As this small high moves rapidly eastward, bad weather and cyclogenesis in the coastal Asian waters often follow in its wake. The reliability of this sequence of events makes the appearance of this surface "bubble high" a good predictor for cyclogenesis and ensuing bad weather, although there have been cases when no cyclogenesis occurred. The critical area for this small migratory high is outlined in Figure 4-5. Obviously there is no significant geographical separation between cases of cyclogenesis and no cyclogenesis. Cyclogenesis should therefore be anticipated for any case of break-off from the cold Asian anticyclone and subsequent move into the critical area delineated in Figure 4-5.

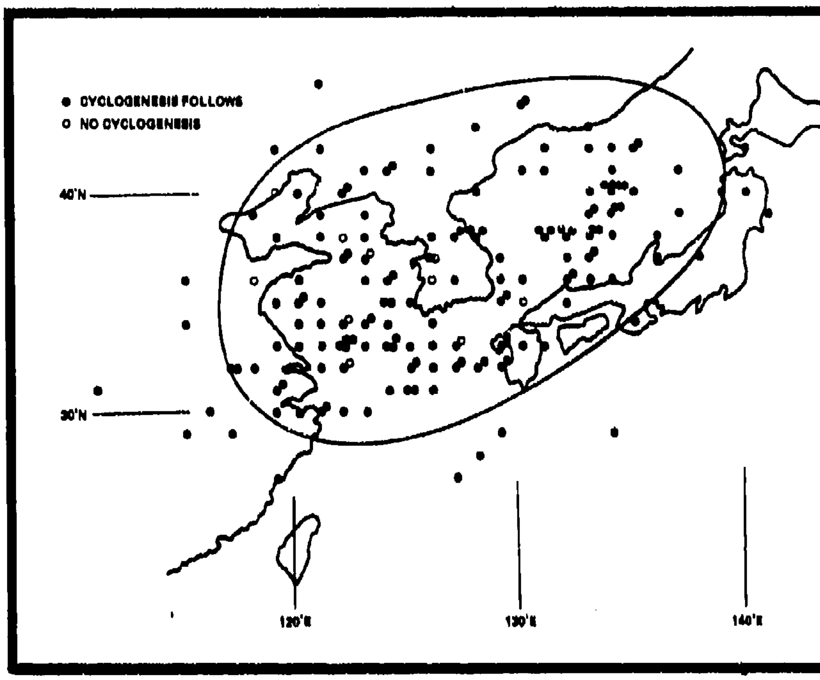


Figure 4-5. Critical area for "bubble highs."

From the location of the critical area, it is possible to determine some of the criteria for cyclogenesis. The thermal contrast between the polar air moving off the cold Asian continent and the adjacent sea areas must be intensified by the southerly flow on the west side of the "bubble." This mechanism explains the rather restricted area to which this method applies.

Once formed, these storms tend to deepen rapidly. In practice, almost any surface cyclonic circulation in this area in winter should be forecast to increase in intensity. Some measure of deepening follows so reliably that it can be predicted with a high degree of confidence.

4.5 FORECAST GUIDANCE

There are certain empirical rules that can aid the operational forecaster in the Korean area. Many of these indicators and relevant discussions are given in several specific areas and a final "miscellaneous" group completes the remainder of this section. Since many of the empirical rules have been developed by the U.S. Air Force in the Korean area, there are frequent references to the USAF-devised Korean forecast areas shown in Figure 4-6.

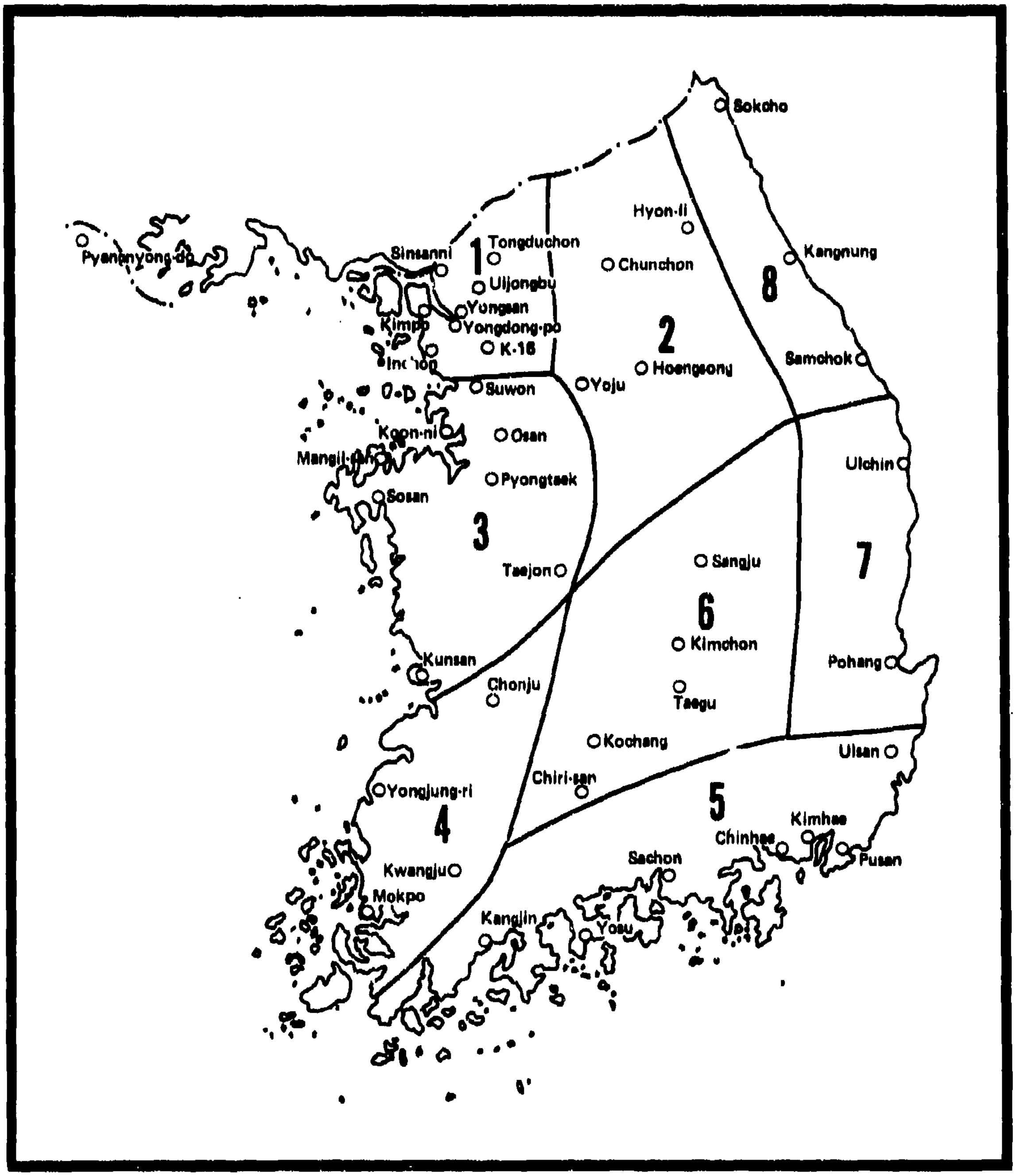


Figure 4-6. South Korean forecast areas as delineated by the U.S. Air Force (from 1st Weather Wing, USAF).

4.5.1 Cyclones

(1) Siberian lows such as Type I and VI (see Para. 4.3) are often weak due to the dry continental air; therefore, there is very little precipitation and variable amounts of cloud both ahead of and behind the associated occlusion or cold front, and there is little change in temperature at the surface. If considerable precipitation and cloudiness are present in the cyclone area, the low, with its frontal system, may be associated with an unstable air mass and move rapidly eastward.

(2) If a low pressure center appears in Manchuria and a wave forms in China near Shanghai with a warm front extending eastward toward Kyushu, Japan, there will usually be a weak trough aloft, orientated north and south and appearing to be aligned with the low center. This trough line will usually move slowly eastward.

Associated with this trough will be marginal weather to the east of the system, improving to the west. If the wave cyclone indicates no rapid development or movement, surface winds on the west and east coasts of the Korean Peninsula will veer from southeasterly to southwest and west on passage of the trough, indicating the approach of a secondary front. The wave cyclone, now over the Yellow Sea or East China Sea, will remain weak and move very slowly east at about 10 kt. As the secondary front crosses the Peninsula, considerable weather and wind from northwest to west, 20-35 kt, may ensue for approximately six hours.

However, if the southerly wave deepens, then a secondary trough to the west may not appear or, if it does, it will be very weak. The weak north-south trough connecting the centers of the two lows will intensify and move easterly at the same rate of speed as the center of the southerly low. Six to twelve hours after the passage of the trough, weather conditions will improve and surface winds will return to west to northwest 20-30 kt. After 24 hours, excellent conditions should prevail over the Yellow Sea and Sea of Japan.

(3) Generally, when cyclogenesis occurs over southeast China near Shanghai, the resulting low tends to move northeast, producing an inverted trough over the Yellow Sea and precipitation along the west coast ahead of the low. During summer months, this type of system will give 2-6 inches of rain to the western region of South Korea. During winter, 2 inches or more of snow is very likely.

(4) If a low moves southeast from Mongolia or Manchuria into the Sea of Japan and no low pressure area exists near the Ryukyus or southern Japan, then its development and movement will be governed by the intensity and position of any low that exists over or near Kamchatka and the 700 mb flow over southern Japan.

If the Kamchatka low is within 1000 n mi (1852 km) of the low in the Sea of Japan, the low in the Sea of Japan will not deepen and will move eastward across northern Honshu. If the two lows are separated by more than 1000 n mi (1852 km), the Sea of Japan low will deepen rapidly and move northeastward. If, at the same time, the 700 mb flow over southern Japan is southwesterly, there will be a rapid spreading of bad weather to the northeastward and two or three days of cold, dry weather will prevail over the Korean Peninsula during the winter months.

(5) During winter, cyclogenesis occurs in the Manchurian basin with the majority of the cold fronts that pass over the Korea-Japan area. Within 24 hours, these lows deepen and move eastward over the Sea of Japan in association with well-defined fronts.

(6) The most hazardous weather in the Japan area, excluding typhoons, is caused by deep lows that form in the vicinity of Okinawa and Taiwan and move northward (of Types III and IV in Figure 4-4). These lows almost invariably show rapid, intense deepening, especially during spring, fall and winter.

(7) A wind flow (from south to east) up to 700 mb from Japan to the Korean Peninsula will produce widespread bad weather in the Sea of Japan that may continue for 72 hours. A series of waves usually exists in association over the East China Sea and along the southern coast of Japan. The wave in the East China Sea may move either into the Sea of Japan or along the southern coast of Japan. The development of these systems is dependent on the proximity of neighboring low centers and the upper air flow pattern.

(8) If a low south of Japan moves in a northeasterly direction so that it reaches a position 1000 n mi (1852 km) or more east or northeast of a low in the Sea of Japan, the low in the Sea of Japan will deepen and move northeastward. If the low south of Japan and the low in the Sea of Japan are within 800 n mi (1482 km) of each other, the former will move eastward behind the Sea of Japan system or be integrated with the latter as it moves into the Pacific.

(9) When the isobars are orientated northeast to southwest in line with the islands of Japan, weak cyclones frequently form off southern Kyushu, Japan. This type of pressure distribution often occurs when cyclones have passed southern Japan. The trailing cold fronts associated with these lows are often slow moving and tend to stagnate off the coast of Japan.

(10) The area around the Shantung Peninsula and the adjacent Gulf of Chihli is a likely place for formation of weak lows at the trailing end of cold fronts oriented west-southwest and east-northeast. In winter, these lows will lower ceilings and visibility in moderate to heavy snow showers over the northwest portion of South Korea.

(11) Deep lows aloft over northern Mongolia, with troughs or fronts extending to the southwest, tend to deepen as they move east-southeast, with the trough/front traveling southeast at 20-25 kt. As the trough approaches the Gulf of Chihli, it tends to slow up slightly as a warm ridge builds ahead of it. There is then a good possibility that a low may develop over the Gulf of Chihli along the trailing edge of the front/trough. This low will then tend to track eastward, giving moderate/heavy precipitation to the northwest corner of South Korea. If the front/trough becomes oriented west-southwest and east-northeast, precipitation will tend to be light.

4.5.2 Low Cloud Cover

4.5.2.1 West/Southwest Region

Gradient level flow from the northwest to southwest, when the air mass is colder than the Yellow Sea, will cause stratocumulus ceilings along the west coast near 3000 ft (914 m) above mean sea level (MSL); a flow with a northerly component greater than 315° will cause only scattered low clouds north of a Mangil-san - Yoju line (Figure 4-6). During warmer seasons, the stratocumulus off the sea will form significant amounts only under cyclonic low level flow, usually preceding a frontal system, and occasionally after a frontal passage for three to six hours when a micro-low cuts off in the Mangil-san - Haeju - Kimpo triangle.

A prolonged southwesterly flow (eight hours or more) will cause broken to overcast ceilings along the south and west coastal islands, but generally only a scattered condition on the mainland in area 5 of Figure 4-6, unless directions are south of 230°. Wind flow of 220° or slightly more westerly will bring broken to overcast stratocumulus and cumulus with bases of 2000-3000 ft (609-914 m) to most of areas 3 and 4 and the northwestern third of area 6. More than four hours of this flow is necessary to advect the cloud layer into area 1, but it is not uncommon during winter months for the clouds to move into area 1 from the Yellow Sea immediately behind a migratory surface ridge-line that has moved over to the east coast.

Similar conditions can be expected with westerly winds in most of areas 1, 3 and 4 with the clouds generally moving further inland, roughly to a Chunchon - Hoengsong - Kimchon - Chiri san - Kangjin line after four to five hours and covering all of South Korea, except the eastern halves of areas 5, 7 and 8, after eight to nine hours.

Northwesterly flow again brings similar conditions, with bases some 500-1000 ft (152-304 m) lower over most of the inland areas and with more cumulus mixed in the overall cloudiness, since the air is usually post-frontal (from the northwest) and therefore colder than the sea surface and more unstable.

Low ceilings similar to those outlined for the east and south coasts with low level southeasterlies are common along the south and southwest coasts when low level and gradient winds are from the south at 10-15 kt for over eight hours. Persistent flow from the same direction over 12 hours will move the cloudiness as far north as a Kwangju - Taegu - Ulsan line.

4.5.2.2 East/Southeast Region

Gradient flow from the northeast to east will also cause low stratus and stratocumulus near or below 1200 ft (366 m) along the east coast from Sokcho south to Pohang. Gradient flow from the east, over 20 kt for eight hours, moves 2500-3000 ft (762-914 m) ceilings westward into roughly the Sangju - Taegu - Sachon line and the same flow persisting for over 12 hours advects the cloud line to within 60 n mi (111 km) of the west coast to blanket Chunchon, Hoengsong, Taejon and Yosu. Ceilings below 2500 ft (762 m) in this western quarter of South Korea should not be anticipated unless continuous precipitation from middle clouds persists for over six hours, at which point low ceilings will begin to form.

Low level winds from the southeast will also cause extensive stratus ceilings along the east and south coasts. Ceilings 200-700 ft (60-213 m) are common when the air is colder than the sea surface, and 800-1200 ft (244-365 m) when the air is warmer than the sea surface. These conditions usually require a surface level flow in excess of 10 kt for over four hours.

4.5.2.3 Inland

Weather regimes that cause widespread low ceilings in the 1000-5000 ft (304-1525 m) above MSL range frequently generate extensive fractostratus in the interior valleys and saddlebacks; these are rarely reported by the widely scattered observing stations. This will cause frequent "in and out" conditions for aircraft operations 500 ft (152 m) or more above ground level (AGL).

With every forecast area of South Korea having terrain over 2000 ft (610 m) and the maximum elevations of 5000-6300 ft (1525-1920 m) scattered around the nation, minimum ceilings of "zero on mountains" can be forecast whenever any broken cloudiness below 5000 ft (1525 m) above MSL is forecast. It is operationally more significant to employ the term "zero on mountains" when ceilings are expected to be at or below 3000 ft (915 m) above MSL for given areas of operation. Note: with three exceptions -- RKNH (Haengsung, Elev. 330 ft/101 m), RKNK (Hyun-Ni, Elev. 890 ft/274 m) and RKTN (Mangilsan, AB Elev. 980 ft/302 m) -- all hourly reporting stations in South Korea are located at elevations at or below 250 ft (76 m) above sea level. For example, with a ceiling of BSC025 at Taejon (RKTD) the <u>maximum</u> ceilings AGL a helicopter

pilot could expect in the passes southeast of Taejon would be 1000 ft (304 m) under optimum conditions. With southerly or southwesterly low level winds, the ceilings would be 500-800 ft (152-244 m) AGL in those same passes.

4.5.2.4 Low Cloud Tops

Stratocumulus cloud layers usually top out at 5000-8000 ft (1525-2440 m) winter and summer. Prefrontal shower activity usually tops out at 8000-14,000 ft (2400-4270 m) in winter and 12,000-18,000 ft (3660-5490 m) in summer. Thunderstorm tops are somewhat lower than is customary over the United States. The average tops are 14,000-20,000 ft (4270-6100 m) in winter with some as low as 10,000 ft (3050 m); in summer, tops will be 25,000-35,000 ft (7625-10,675 m) with some extremely rare late summer and fall cumulonimbus tops (with very well-defined cold fronts) reaching as high as 48,000 ft (14,640 m). Stratus along the west coast and over the Yellow Sea usually tops out at 1200-1800 ft (366-548 m); along the east coast, it is usually somewhat thicker with tops around 2000 ft (610 m).

4.5.3 Medium/High Cloud Cover

4.5.3.1 General

Middle and high cloud forecasting (yes or no) can be accomplished with a fair degree of accuracy by noting and advecting cold pockets of air at these levels, and assuming cloud cover appears as the cold pocket traverses South Korea. (The boundary of cold and warm pockets located over central China is a likely place for front or trough development.)

4.5.3.2 Medium Cloud Tops

Altocumulus and altostratus clouds based at or below 10,000 ft (3050 m) usually top out at 12,000-14,000 ft (3660-4270 m). Altocumulus occasionally occurs over and to the west of the central mountains and runs the entire length of the Korean Peninsula, normally topping out at 9000-10,000 ft (2745-3050 m). It is probably more frequent over and to the east of the east coastal mountain ridge, although rarely reported. Under strong westerly flow (over 30 kt) at and above 2000 ft (610 m) above MSL, it is likely that altocumulus would be widespread in areas 7 and 8 (Figure 4-6) and should top out at 12,000-14,000 ft (3660-4270 m). Merging middle layers, changing to nimbostratus as a Shanghai low approaches from the southwest, top out at 22,000-28,000 ft (6710-8540 m) with the tops dropping to 14,000-16,000 ft (4270-4880 m) on passage of the low system. Tops decrease to 10,000-12,000 ft (3050-3660 m) over most of South Korea as the system moves off the southeast coast into the Sea of Japan. Altocumulus castellanus occurs infrequently, usually during the spring and early fall. It is usually based at 8,000 ft (2440 m), topping out at 14,000-16,000 ft (4270-4880). Rarely is it extensive enough to cause a ceiling.

4.5.3.3 High Cloud Tops

Cloudiness associated with the jet stream will level off within 2000 ft (610 m) of the tropopause, usually at or somewhat above it in eastern Asia. Widespread cirrus and cirrostratus in advance of major systems, usually Shanghai lows, top out at 35,000-38,000 ft (10,675-11,590 m) except in late spring and early fall when they often reach to 40,000-45,000 ft (12,200-13,725 m). These tops will drop steadily as the overrunning warm ridge in advance of the storm moves eastward and tops fall into the middle cloud range.

4.5.4 Precipitation

4.5.4.1 Frontal/Low Pressure Precipitation

A wider band of precipitation occurs with northeast-southwest oriented fronts than with west-east or north-south oriented fronts.

Steady rain is usually of light intensity in the northern third of South Korea. Systems intense enough to cause widespread precipitation over all of South Korea usually cause moderate to heavy rains again in the southern mountains. The greatest amounts from a storm transiting the straits south of the Peninsula or along the southern coast usually occur in the Pohang, Ulsan, Pusan, Mokpo, Taegu, Pohang triangle where accumulations of 6-10 inches in 24 hours are not uncommon.

Orographic effects must be considered in determining precipitation intensities. Southeasterly flow in advance of a Shanghai low passing south of Sachon will -- because of the readily available moisture source, the quadrant of the storm and the sharp rise in terrain from the sea to nearly 5000 ft (1525 m) above MSL -- deposit rain in quantities double or triple the amounts that would normally be expected from a similar storm over flat terrain or over a more continental environment.

Precipitation is not normally forecast when low level and gradient northerly winds are forecast over South Korea. The exceptions are:

(1) Areas 1, 2 and 3 (Figure 4-6) - When gradient flow is between 330° and 030° at velocities greater than 20 kt for more than six hours, a micro-low can be expected to develop under straight-line or cyclonically curved flow at 850 mb and 700 mb. The low will develop in the Mangil-san, Haeju, Kaesong triangle causing extensive stratocumulus and cumulus ceilings northwest of a Suwon - Chunchon line together with frequent patchy light rain or rain showers for six to eight hours.

(2) Slow moving east-northeast to west-southwest fronts that move down and become oriented east to west across South Korea -- with a high centered in eastern Siberia causing north-northeast winds in the lower 3000 ft (915 m) over the northern half of South Korea -- usually have considerable overrunning aloft from the south or southwest, causing persistent precipitation for 6-12 hours along a band 20-50 mi (32-50 km) north of the front.

Precipitation associated with northeasterly low level winds usually consists of steady light snow in the winter months along the northeast and east coasts of areas 7 and 8 (Figure 4-6) and drizzle in the warmer months. In areas 5, 6 and 7, precipitation is not normally forecast unless the northeast winds are part of a major storm circulation. The same situation can be generally forecast also for easterly flow, although the precipitation does extend somewhat further south along the coast to cover most of area 7. In neither case does the precipitation generally extend inland past the ridge of the Taebaek Mountains; it will do so only when the winds persist for over 12 hours in the 15-20 kt range with a long fetch over the Sea of Japan.

4.5.4.2 Convective/Orographic Precipitation

Most heavy or moderate precipitation, rain or snow is in the form of convective shower activity. This does not preclude the occurrences of steady moderate or heavy precipitation from major storm systems transiting South Korea. Steady snow is usually of light intensity, unless caused by a major storm system approaching from the west or southwest. In such a case, the intensities are usually moderate, though occasionally heavy in the interior as the storm transits southern or central South Korea into the Sea of Japan.

Northwesterly flow causes primarily convective types of precipitation in most areas, with the possible exception of areas 1 and 2. The most common eastward boundary of precipitation is the Seoul - Hoengsong - Kimchon - Chiri san - Mokpo line. Coastal areas in area 4, especially Kunsan, get their greatest snowfall amounts and lowest wintertime ceilings and visibilities under prolonged northwesterly flow.

Southwesterly flow and westerly flow causes primarily convective types of precipitation initially in areas 3 and 4; after four to six hours, this spreads inland to areas 1, 2, 3, 4 and 6. Low level flow from these directions usually precedes an approaching cold front from the northwest and the precipitation that is not directly associated with the front itself will last only so long as there is cyclonic shear and/or curvature in the lower 8000 ft (2440 m). In summer months, with the polar front north of South Korea, orographic thunderstorms are initiated under southwesterly flow and persist on some mountain slopes for as long as 24 hours, particularly just east and northeast of the Kwangju and Chonju areas. With westerly flow, the eastern extent of the showers is much greater, often reaching all areas with the exception of 7 and 8 In the warmer months, precipitation is more likely to be of a convective type with orographic considerations playing a larger part in the precipitation process and the showers inclined to spread further inland.

4.5.4.3 Freezing Precipitation

Freezing precipitation is very rare on the Korean Peninsula. When it does occur, it is usually confined to mountain top stations where radar and/or communications sites are located. No weather stations are located at these points, so little if any warning or immediate notification of occurrence can be expected. This freezing precipitation is the result of residual morning radiation inversions that become nearly, but not completely, eradicated due to warm southerly flow and rain falling from warm middle levels. These localized patches of sub-freezing air are usually situated on the lee side of the affected mountains and are from 500-1500 ft (152-457 m) deep and based around 1000 ft (304 m) above MSL. They are very persistent and last from four to six hours after all nearby reporting stations have reported temperatures in the high 30's and low 40's (°F).

4.5.4.4 General Trends

During the winter months, precipitation is usually light snow or drizzle in area 5 and the southern part of area 4. In the warmer months, precipitation is more likely to be of a convective type.

Under a southeasterly flow, precipitation is usually confined to areas 5 and 7 unless it persists for over eight hours; after this, it will have driven enough moisture inland to cause some orographic precipitation in area 6.

4.5.5 Visibility and Fog Formation

Visibilities aloft tend to be less than those reported by surface observations, particularly in snow (at all levels up to the cloud base), in fog (from about 200 ft (60 m) AGL to the top of the inversion) and to a lesser extent in rain.

In spring, strong winds up to 20,000 ft (6100 m) and above, assuming there is no precipitation, will often lower visibilities to a mile or less at the surface and 3-5 mi (5-8 km) above 500 ft (152 m) AGL as a result of blowing dust. Two or three times each spring extensive dust and sand from the Gobi Desert will lower visibilities all over South Korea to 2-4 mi (3-6 km) from the surface to approximately 25,000 ft (7625 m).

Lowest visibilities under winter radiation fog conditions are usually west and north of a line from Checkpoint 7 (in the western DMZ) - Uijongbu - Yoju - Taejon - Mangil-san (Figure 4-6).

In the absence of fog, but with a significant radiation inversion during winter months, smoke is the predominant restriction and is usually concentrated around the industrial cities. A detailed pressure analysis (1.0 or 0.5 mb intervals) or a streamline analysis of 2100Z and/or 000Z data will show regions of cyclonic convergence where smoke and haze will be concentrated

and very persistent, often until noon or later. The most frequent restriction to visibility is fog (see Para. 3.3.5).

The following conditions provide guidance for anticipating possible fog formation:

(1) The appearance of a weak trough aloft or quasi-stationary front oriented east-northeast to west-southwest.

(2) Pre-frontal fog associated with an approaching low from the west.

(3) Light southerly winds that persist for several days and originate from the Pacific High. The warmer and more moist the air mass, the greater the density and extent of the fog.

(4) Fog will frequently form on the western side of a high pressure cell if winds are light.

(5) Knowledge of sea isotherms and currents in the Sea of Japan and Yellow Sea will reveal cold pockets of water where fog will form.

(6) Sea fog in the Inchon area has a tendency to dissipate earlier each day with the progression of spring.

(7) As the Yellow Sea warms up during late spring the low, dense, morning stratus is replaced by thin layers at 800 to 2000 ft (244-610 m). Fog sometimes forms instead of stratus, especially if haze or dust were present at sunset the previous evening.

(8) Ice fog occurs very rarely in winter; a temperature below -20°F, snow cover and clear skies at night are necessary for it to form.

4.5.6 Winds

During winter months, the winds aloft tend to be west-southwest to northwest. In summer, they are predominantly southwest to south-southeast. Under stagnant air mass conditions or weak northwesterly flow, a micro-anticyclone forms and intensifies daily in the Hoengsong-Taegu-Suwon triangle.

In summer, winds from the surface to 3000 ft (915 m) will be south-southeast at 10 kt from 0300-0900 LT, veering to south-southwest at 10-15 kt by 1200 LT in areas 1, 2, 3 and 4 (Figure 4-6).

In late fall, winter and early spring, winds from the surface to 1000 ft (304 m) will be northeast-southeast 5-8 kt from 0600-1100 LT, backing to west-northwest to north at 8-12 kt by 1300 LT in areas 1, 2, 3 and 4.

Winds in the surface to 5000 ft (1525 m) layer in winter are usually the strongest during the period 18-24 hours after a cold frontal passage or the passage of a well developed surface low. Gusty surface winds are usually experienced immediately after frontal passage.

Winds aloft from the surface to 10,000 ft (3050 m) often become stronger over South Korea 12-24 hours before the area is actually within the circulation (200-250 mi/322-402 km away) of an approaching low or strong front.

During winter, a "rule of thumb" for figuring the maximum wind speed along the west coast under strong northwest flow is to take 2/3 of the maximum wind gust at P-Y-DO (Station No. 103).

4.5.7 Thunderstorms

Severe thunderstorms/tornadoes are rare in South Korea, south of a line from Pyongyang to Wonsan.

Air mass thunderstorms are likely in most areas in summer if: winds for the first 5000 ft (1525 m) are light and variable; very little middle and/or high cloudiness exists; temperature is forecast to be greater than 80°F by noon; air is more unstable at 1200Z than at 000Z the night before; and wet-bulb zero height is 12,000 ft (3660 m) or less.

Thunderstorms occurring in the Kwanju-Mokpo area are usually under a southwesterly flow and are frequently the southern end of a fairly broad, curving, northwest-southeast instability line that will move north-northeast; Osan will experience thunderstorms 3-5 hours after Kwangju, with the line by this time extending into the Sachon region. Yonsan will then have the thunderstorms 5-7 hours after the line has passed through Kunsan, with the line extending south-southeast towards the Chinhae-Kimhae area.

4.5.8 Turbulence

Severe turbulence will be widespread over all South Korea with the winds at 1000-3000 ft (304-415 m) at or above 30 kt when directions are 060-130° or 240-310°. Moderate to severe turbulence will be experienced in hilly country especially along the higher ridge lines, whenever the gradient level winds (1000-2000 ft/304-610 m) exceed 20 kt.

The height of the turbulent layer will usually be twice the average height of the terrain over which the strong winds are blowing. This can be revised when a significant radiation inversion (over 5°C/1000 ft) exists just above the surface and the winds are blowing at the inversion level. Then the base of the turbulent layer will be approximately 300-500 ft (90-152 m) below the top of the inversion.

Drainage plus strong gradient level winds, plus a strong 850 mb thermal gradient from north to south, will cause gusty surface winds in the early morning hours in the Pusan area in the winter months; this is especially true at Pusan International Airport, which is uniquely situated at the southern end of a north-south-oriented valley 10 mi (16 km) long. Gusts often reach peaks of 35-55 kt within an hour after sunrise and have been reported as high as 65 kt in less than 30 minutes after calm winds had been reported. (Since March 1976, studies have been undertaken to determine objective methods to forecast this localized phenomenon at least 12 hours in advance.) These winds cause severe turbulence up to 4000 ft (1219 m) in and south of Pusan, but show little or no effect some 5 mi (8 km) east or west of the airport.

During the warmer months of the year, whenever convective cumulus is forecast, nearly continuous light turbulence should be forecast in all areas, especially where there is a 10 kt sea breeze expected just inshore from the beach. The base of this turbulence will usually be about 500-800 ft (152-244 m).

Jet stream turbulence is most prevalent between the 400 and 300 mb levels. It is usually experienced along the northern side of the jet in the cold air where there is a maximum packing of isotherms. It is more apt to be felt with jet velocities ranging from 50 to 90 kt than with velocities greater than 100 kt. A secondary region of turbulence is normal in the layer between 250 and 150 mb and is prevalent south of the jet maximum.

4.5.9 Aircraft Icing

Aircraft icing is generally limited to those clouds in which the temperature is between 0°C and -20°C, with the type of icing largely dependent on drop size, rate of accretion and temperature. Factors that favor clear ice formation are temperatures from 0°C to -4°C, rapid accretion and large drop size, normally found in cumuliform clouds. Rime ice formation is favored by small drop size as found in stratiform clouds, slow accretion and temperatures about -10°C or cooler. However, at temperatures of -20°C or colder, the moisture content of the air is usually too low for all forms except very light rime icing.

Moderate to severe mixed or clear icing occurs at and above the freezing level in towering cumulus and cumulonimbus. Normally, this would be above the operational flight levels of helicopters, but could be of concern to fixed wing aircraft.

Icing of the greatest concern for rotary wing aircraft is the light to occasionally moderate rime that occurs in clouds (and snow below the clouds) when the western half of South Korea is under the influence of a moderate, cold, unstable west to northwest flow off the Yellow Sea and the freezing level is between the surface and 5000 ft (1524 m) during the period late October through late March. This is also the case to a lesser extent under an east to northeast flow along the east coast.

Heavy frost or freezing fog in protected valleys is a frequent occurrence in the late fall and early spring after a rapid clearing and diminishing wind conditions following a late afternoon or early evening cold frontal passage, where there were significant amounts of rainfall.

4.5.10 The Jet Stream

Jet stream characteristics are listed below to provide forecast guidance during analysis of changing synoptic conditions at the surface.

(1) When a migratory low deepens, the jet stream over it generally intensifies and descends to a lower height.

(2) Occasionally, when an upper ridge of high pressure moves over the region, the band of maximum westerlies ascends, the band's speed decreases, and unstable jets can be found when polar outbreaks occur.

(3) Polar jet streams rarely show mean pattern characteristics on any given day, whereas the subtropical jet is remarkably uniform.

(4) During fall, winter and spring, the subtropical jet most frequently lies over the section of 500 mb isotherms between -10°C to -15°C; the polar jet is generally located over 500 mb isotherms between -15°C to -20°C in spring and fall, and between -20°C to -28°C in midwinter.

(5) Polar jets are often related to polar fronts. In such cases the jet center usually lies over or slightly south of the 500 mb frontal position, especially after fresh polar outbreaks from Asia.

(6) The winter mean jet stream speed is 155 kt. The daily range of maximum wind speed is 120-250 kt. Higher speeds generally occur in jets located between 30°N and 35°N.

(7) In rare instances jet intensities may reach values of 150-200 kt following the genesis of a well-defined low north of Japan in summer.

(8) The subtropical jet's mean intensity during spring and fall is about 120 kt with mean monthly ranges from 70 to 140 kt. The polar jet's mean speed during these seasons is 100 kt and its monthly values range from 60 to 110 kt. From day to day, jets have speeds varying between 50 and 200 kt.

(9) The greatest wind shear, 100 kt/100 mi (161 km), is usually observed on the north side of the jet, but occasionally it is as strong to the south. South side shear usually has ranges of up to 100 kt/300 mi (483 km). Clear air turbulence can be expected with high shear values.

(10) Vertical shear is generally strong below intense jets. At 10,000-15,000 ft (3048-4572 m) levels below jet centers, values of 50 kt/1000 ft (304 m) occasionally occur, especially in the vicinity of and above the polar front.

(11) The strongest jets during all months are associated with cyclogenesis or the movement of a pronounced low across the 130° and 140°E meridians. The strength of the jet increases quite markedly over regions west of the surface position of such a low. As a rule, the more intense the low, the greater will be the maximum wind speeds in the trough of the upper troposphere.

(12) Jet streams with center speeds of 50-100 kt greater than the monthly mean often overlay regions dominated by surface high pressure areas.

(13) Minimum speeds or weak jets are usually associated with well-defined ridges aloft. In such cases the center of maximum winds may be displaced vertically with below-normal speeds -- or the horizontal axis of maximum winds may be displaced northward -- and above-normal maximum winds will be found well to the north beyond the top of the ridge.

4.5.11 Miscellaneous Forecast Guidance

(1) A good average speed for relatively shallow troughs moving from west to east is 15 kt (3° of latitude every 12 hours) over land and 20-25 kt over water.

(2) When the 500 mb chart shows a deep low aloft northwest of the Korean Peninsula with a deep trough extending south to southwest through the Yellow Sea, frequent trough passages can be expected about every six hours for about 24 hours.

(3) Any kind of trough or front in the Yellow Sea will tend to set off isolated rain showers along the west coast from Kunsan to Osan between 0500 and 1100 LT with broken low and medium level cloudiness during this period extending along the entire west coast. Cumulonimbus clouds and/or thunderstorms are very likely to develop in that area after 1200 LT and move northeast.

(4) Low level air flow in winter from about 290° to 120° tends to give clear, cold weather to South Korea. Winds from any other direction tend to produce cumulus buildups and scattered snow showers along the west coast, with ceilings and visibilities in the vicinity of showers lowering to about 2000 ft (610 m) and 1½ mi (2.5 km), respectively.

(5) In winter, strong northwesterly flow usually indicates the beginning of three to five days with fair skies, cold temperatures and no precipitation. After the third day, morning fog/smoke will often develop between 0800 and 1100 LT.

(6) Approximately 36 hours after the initial outbreak of cold flow, a lee side trough usually forms along the east China coast. It should not be forecast to move until an upper air trough approaches it.

(7) A ridge will maintain itself or build if analysis of present and past 12 hr upper air maps shows warm air entering the high center from south to west, assuming the high is warm-cored. (If the high is warm-cored, it will show up at 500 mb level.)

(8) During summer and winter, the central regions of South Korea will have the lowest minimum temperatures under clear skies/calm wind conditions. Maximum temperatures in summer will often occur near the DMZ rather than along the southern coast.

SECTION 5

CONTENTS

5. PORT FACILITIES AND SHIPPING ACTIVITIES

5.1 INTRODUCTION

The volume of South Korean coastal shipping activities developed rapidly during the late 1960's and early 1970's; in the period 1967-71, coastal shipping captured 46% of the total increase in all freight traffic. By 1971, the total traffic handled through South Korean ports had increased to 51 million tons from a modest 7.5 million tons in 1962. This spectacular growth in foreign trade and increase in coastal traffic, due largely to industrial expansion, has fostered a continuing effort to expand and improve port facilities around the Korean Peninsula. Despite South Korea's long and indented southern and western coastlines, there are few good natural harbors; the best one is at Pusan.

In 1973, there were 40 so-called "designated harbors" under the control of the Ministry of Transportation. Seventeen were classified as first-class ports and five of these -- Pusan, Inchon, Ulsan, Mukho and Pohang -- accounted for the bulk of marine traffic. In 1974, Pusan alone processed 20,392 ships discharging 24,143,000 metric tons of cargo. Major ports utilized by the U.S. Navy are shown in Figure 5-1.

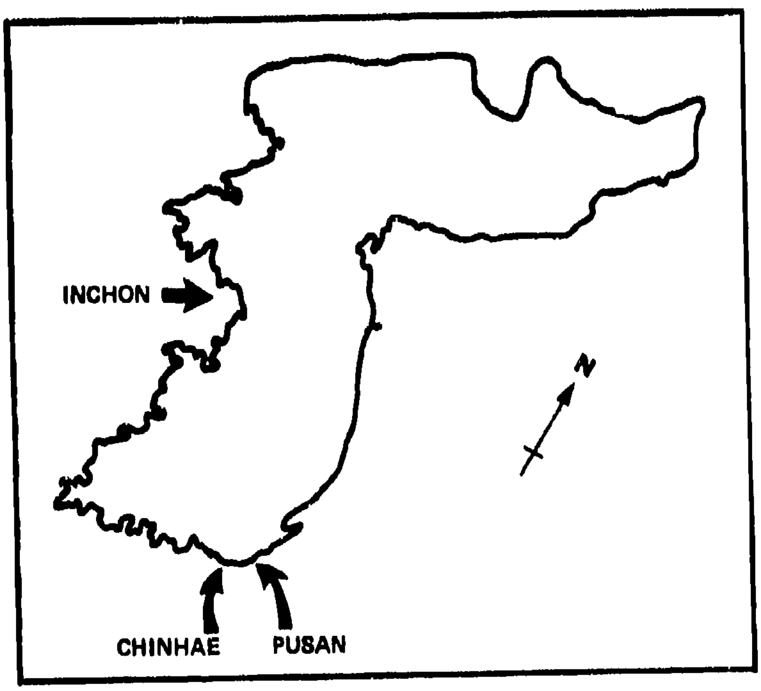


Figure 5-1. Locations of the ports of Inchon, Pusan and Chinhae.

Increasing freight volume during the late 60's generated intense pressures on existing harbor facilities and by the early 1970's, several improvements had been made. In 1974, plans were put into effect to increase the capacity of Pusan Harbor and to establish the Korean Port Authority, an agency that would eventually control and improve operations at all first-class ports. A major new facility at Inchon was completed by constructing a series of locks to enclose the basin against tidal range and enable larger ships to berth there. At the time of its completion in 1974, it provided the largest dock in Asia.

The three major South Korean ports used by U.S. Navy vessels (Figure 5-1) are described in detail in this section. Fishing fleet activities around the Korean Peninsula are also discussed.

5.2 INCHON

5.2.1 General Port Description

Inchon is situated at 37°28'N, 126°37'E on the west coast of the Korean Peninsula. Seoul, the South Korean capital, is approximately 20 mi (32 km) to the northeast. Inchon, which serves as the commercial outlet and port of entry for Seoul, is one of the largest cities in South Korea. It is built around the estuary of the Yom Ha River, a tributary of the 320 n mi (593 km) Han River which flows past the capital (Figure 5-2). The harbor at Inchon, one of South Korea's largest deepwater ports, comprises an outer harbor, an inner harbor for coastal vessels, and tidal basin completed in May 1974 to receive ocean-going vessels (Figure 5-3). For those ships not afforded the protection of the tidal basin, the area of least topographical protection in the outer harbor is to the southwest.

The outer harbor (in the Yom River area) serves as the anchorage for deep draft vessels awaiting berthing instructions for the tidal basin or for vessels discharging logs or cargo specified as dangerous by the Director of Marine Affairs. Many of the cargo operations in this outer harbor are handled by barges. U.S. Navy ships in the past have generally been assigned anchorages E-3 or E-4 (Figure 5-3). More recently the tidal basin has been used, but the high cost of an alongside berth in the basin may make this an infrequent practice. The holding action of the outer harbor bottom is best in the B anchorages, as opposed to the A anchorages in the northern part of the harbor which offer poor holding because of the rocky bottom.

The inner harbor is used only by coastal vessels and is located south of South Wolmi Do (Figure 5-3).

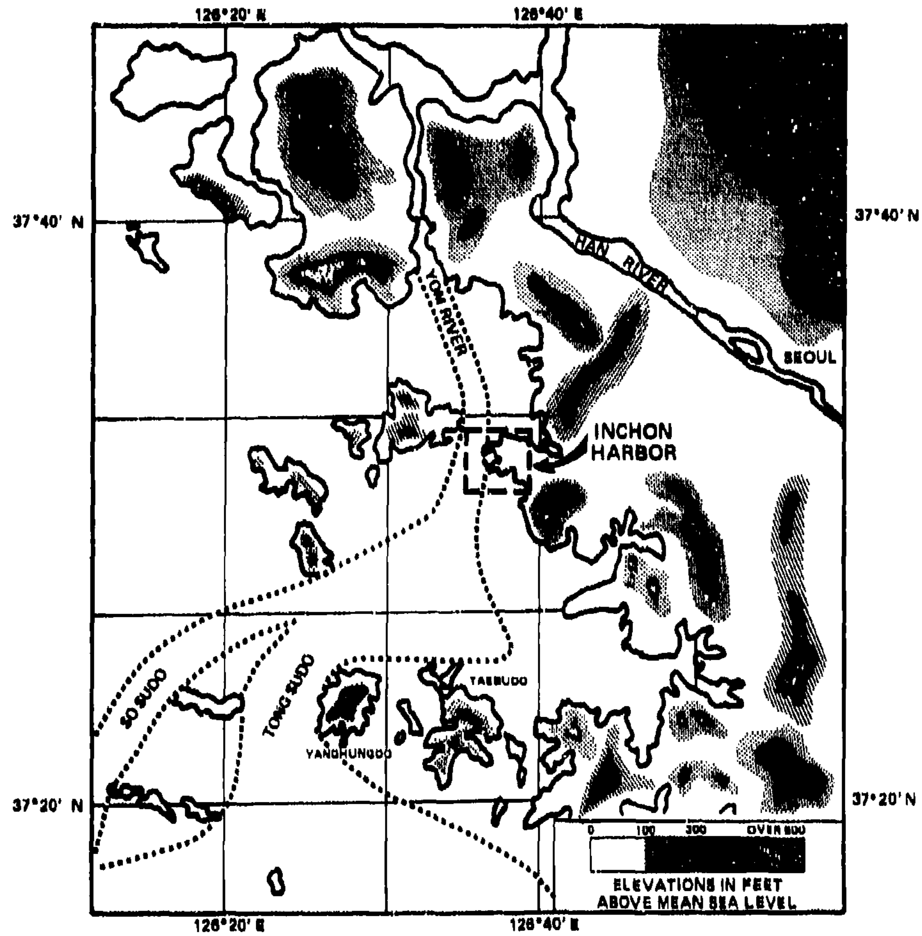
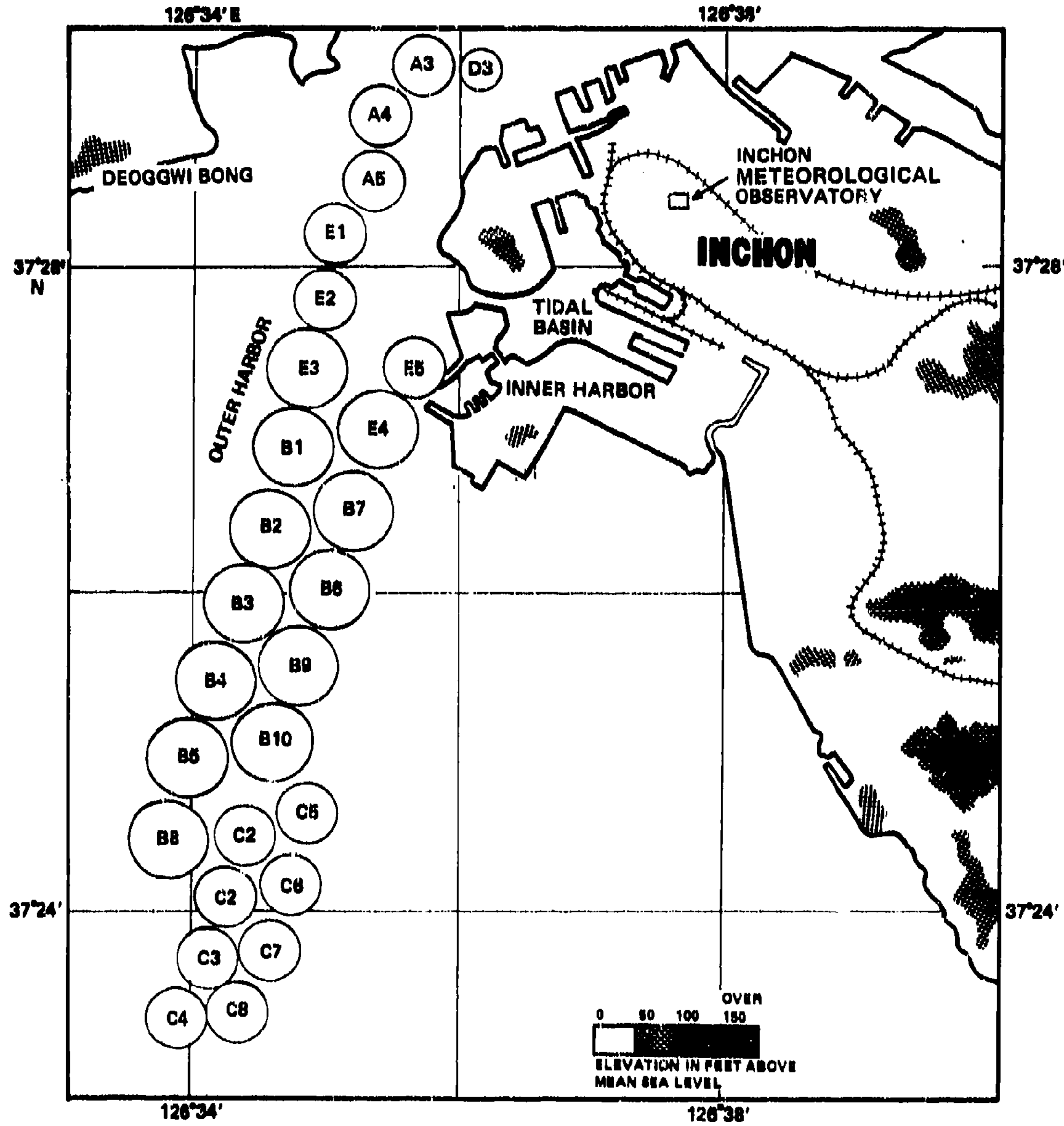


Figure 5-2. Approaches to Inchon Harbor.

The tidal basin is entered through either of two rolling slide locks located between Wolmi Do and South Wolmi Do; these represent the dividing line between the tidal basin and outer harbor. Because the currents in the vicinity of the lock gate run perpendicular to the lock entrance, the tidal basin is entered only at slack tide. It takes approximately 1-1½ hours to clear the lock. Depths within the main port of the tidal basin are 4-5 fathoms (7-9 m); the facility can generally accommodate vessels drawing up to about 27 ft (9 m).

A detailed description of available facilities is contained in Volume V, Section B3 of CINCPACFLT Port Directory or the Far East Port Directory, MSCFE Instruction 3170.4A, Section II-4.



ALL ANCHORAGES WERE RENUMBERED AT INCHON IN 1975. CHARTS SHOULD BE DATED SEPTEMBER, 1975 OR AFTER TO REFLECT THIS CHANGE.

Figure 5-3. Anchorages in the port of Inchon.

5.2.2 Berthing Facilities in the Tidal Basin (Figure 5-3)

(1) The port of Inchon is controlled and managed by the office of the Marine Bureau, Ministry of Transportation, within the harbor limits of 5.4 n mi (10 km) in radius at/from the north corner of Pier One lock entrance. Basin depths are 36-42 ft (12-14 m). Berthing capacities in the tidal basin area are:

Vessel Gross Tons	Available Berths
2,000	4
4,500	3
8,000	9
10,000	3
20,000	3
30,000	1
40,000	1

(2) A total of 25 vessels of various sizes can be accommodated simultaneously, and those vessels will be berthed in four piers in the basin area:

Pier One maintains three berths (1-3) for 2000-3000 tonners.

Pier Two maintains ten berths (4-13) for 3000-15,000 tonners.

Pier Three maintains seven berths (14-20) for 8000-15,000 tonners.

Pier Four maintains five berths (21-25) for 15,000-50,000 tonners.

(3) Lock Chamber (dimensions in feet/meters):

Lock Chamber Specifications	Up to 50,000 G/Tonners	Up to 10,000 G/Tonners
Length Overall		
Inner gate side	889/271	584/176
Outer gate side	987/301	659/201
Width Overall		
(Beam)	118/36	74/22.5
Height Overall		
Frame lock still	60.6/18.5	60.6/18.5
Frame lock chamber	62/19	62/19

(4) Lock Gates (dimensions in feet/meters):

Gate Specification	Up to 50,000 G/Tonners	Up to 10,000 G/Tonners
Length Overall	124.6/38	80.4/24.5
Height Overall	60.6/18.5	60.6/18.5
Width Overall	27.2/8.3	21/6.4
Weight	1050 k/tons	590 k/tons
Opening/Closing Time	5 min	4 min

5.2.3 Stream Anchorages

The following anchorages are reserved for vessels awaiting berthing instructions in the basin, or discharging logs, POL products and other dangerous cargo as specified by the Director of Marine Affairs (depths in feet/meters):

(1) ALFA Anchorages

Anchorage	Position	Depth (at low tide)	Remarks
ALFA-1	37°29'56"N, 126°36'05"E	41/12.5	Open
ALFA-2	37°29'32"N, 126°36'02"E	30/9	Open
ALFA-3	37°20'15"N, 126°35'44"E	42/12.8	Open
ALFA-4	37°28'56"N, 126°35'25"E	30/9	Open
ALFA-5	37°28'33"N, 126°35'20"E	24/7.3	Open
ALFA-6	37°28'11"N, 126°36'08"E	36/11	Reserved
ALFA-7	37°27'57"N, 126°35'30"E	30/9	Not useable
ALFA-8	37°27'23"N, 126°35'04"E	36/11	Open

(2) BRAVO Anchorages

Anchorage	Position	Depth (at low tide)	Remarks
BRAVO-1	37°27'22"N, 126°34'59"E	30/9	Reserved
BRAVO-2	37°26'54"N, 126°34'45"E	30/9	Reserved
BRAVO-3	36°26'24"N, 126°34'35"E	30/9	Reserved
BRAVO-4	37°26'35"N, 126°34'24"E	30/9	Open
BRAVO-5	37°25'27"N, 126°35'13"E	36/11	Open
BRAVO-6	37°34'58"N, 126°33'58"E	42/12.8	Open
BRAVO-7	37°27'00"N, 126°36'25"E	42/12.8	Reserved
BRAVO-8	37°26'30"N, 126°35'11"E	30/9	Reserved
BRAVO-9	37°26'00"N, 126°35'02"E	36/11	Open
BRAVO-10	37°25'032"N, 126°34'51"E	42/12.8	Open
BRAVO-11	37°25'08"N, 126°34'36"E	42/12.8	Open

(3) CHARLIE Anchorages

Anchorage	Position	Depth (at low tide)	Remarks
CHARLIE-1	37°24'29"N, 126°34'26"E	36/11	Open
CHARLIE-2	37°24'07"N, 126°34'17"E	36/10.6	Open
CHARLIE-3	37°21'37"N, 126°34'08"E	33/10	Open
CHARLIE-4	37°21'21"N, 126°33'55"E	36/11	Open
CHARLIE-5	37°24'37"N, 126°34'52"E	28/8.5	Open
CHARLIE-6	27°24'10"N, 126°24'45"E	30/9	Open
CHARLIE-7	37°23'47"N, 126°34'36"E	24/7.3	Open
CHARLIE-8	37°23'25"N, 126°24'21"E	21/6.4	Open

(4) DELTA Anchorages

Anchorage		Depth (at low tide)	Remarks
DELTA-1	37°29'45'N, 126°36'30"E	33/10	Open for Logcarriers
DELTA-2	37°29'28"N, 126°36'18"E	33/10	Open for Logcarriers
DELTA-3	37°29'15"N, 126°36'15°E	40/12	Open for Logcarriers

(5) TANKER Anchorages

Anchorage			
KyungIn-Energy Dolphine Pier	37°30'12"N, 126°36'19"E	44/13.4	Tankers Only
HoNam Tanker Buoy	37°29'05"N, 126°35'58"E	33/10	
Koco Tanker Buoy	37°26'30"N, 126°35'30"E	42/12.8	

5.2.4 Climatic Summary

Figure 5-4 summarizes monthly climatic data for Inchon (the port remains ice-free throughout the winter). Southwesterly winds predominate through the months of April to August (see wind roses, Figure 5-5); with the exception of threatening typhoon situations, such winds are usually less than 15 kt. Wave height, generally 4 ft (1.2 m) or less, presents little problem at Inchon. Wave height data from 1963-70 showed that 99% were 7 ft (2 m) or less with the majority (74%) being 4 ft (1.2 m) or less. Table 5.1 summarizes the percent frequency of given wave heights versus duration period.

Table 5-1. Percent frequency of wave height vs. wave period.

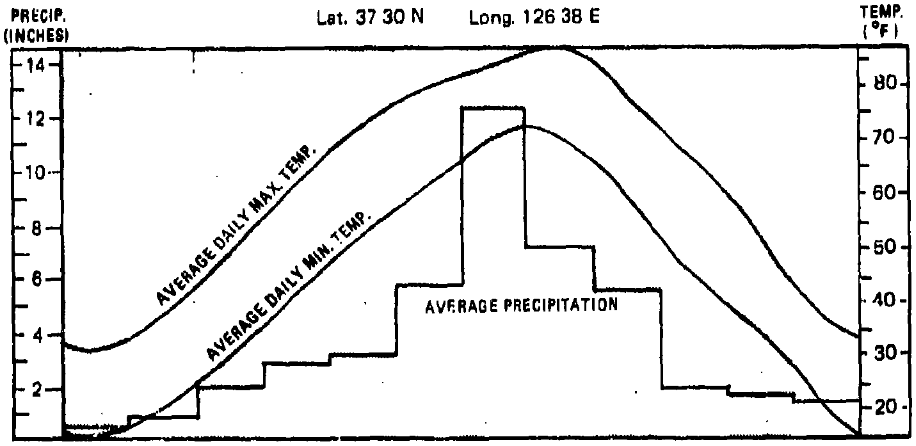
Period (sec)	Percent Frequency of Wave Height (ft)								
	<1	1-2	3-4	5-6	7	8-9	10-11	12	13-16
<6	2.6	29.0	18.2	4.7	1.4	.3	.1	.1	.0
6-7	.1	2.3	4.9	5.3	3.1	.9	.7	.2	.1
8-9	*	.3	.9	.9	.7	.7	.4	.2	.2
10-11	.0	.1	.2	.2	.3	.2	.1	*	*
12-13	.0	*	*	*	*	.1	.1	.0	*
>13	.0	.0	.0	*	*	*	.0	.0	*
Total obs	661	1360	1067	498	250	99	66	23	19
%	16.5	34.9	26.1	11.9	5.9	2.4	1.5	.5	.4

*Indicates percent frequency >0 and <0.05

INCHON, KOREA

Elev. 230'

Lat. 37 30 N Long. 126 38 E



MEAN NUMBER OF DAYS WITH PRECIPITATION, THUNDERSTORMS, FOG

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	7	5	6	8	9	9	15	12	9	7	9	9
	0	0	<1	<1	1	1	1	2	<1	<1	<1	0
	14	12	12	12	11	15	19	16	17	19	18	15

TOTAL PRECIPITATION / SNOWFALL (INCHES)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
•	0.60	0.70	2.00	2.60	2.90	5.50	12.00	7.10	5.40	1.80	1.40	1.20
*	4.9	3.8	1.2	0	0	0	0	0	0	0	0	0.9

MEAN RELATIVE HUMIDITY (PERCENT)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
65	63	66	68	71	75	81	76	72	68	68	66

MEAN TEMPERATURE (°F)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
24	29	38	52	62	71	77	79	69	56	42	29

ABSOLUTE MAXIMUM/MINIMUM TEMPERATURE (°F)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
55	60	71	81	88	91	99	98	90	83	72	58
-6	-1	7	27	38	48	57	60	42	30	13	-1

PREVAILING WIND DIRECTION / MEAN SPEED (KNOTS)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
NNW	NW	NW	SSW	SSW	SW	S	SW	NW	NW	NW	NW
7	9	11	8	6	5	6	4	6	9	9	7

Figure 5-4. Summary of monthly climatic data for Inchon.

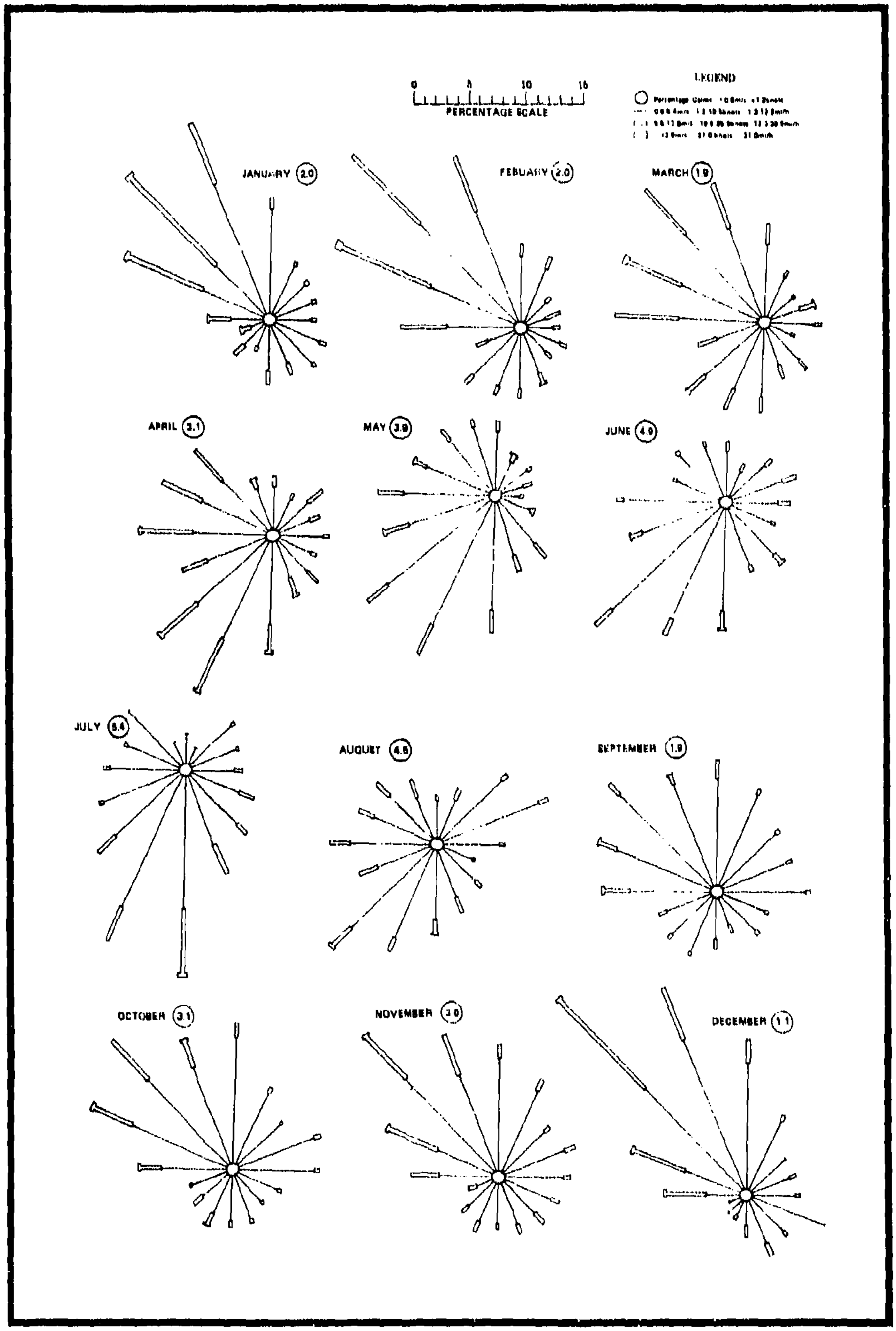


Figure 5-5. Monthly wind roses for the Inchon area (from Climatic Atlas of Korea, 1962).

The most troublesome climatic element at the port of Inchon is probably the frequent incidence of summer fog during the months of March through July, and the predominance of fog in June and July. Such frequent occurrences, particularly in the form of morning fog, make approaches and exits from Inchon difficult. The Tong Sudo (East Channel) is generally recommended to U.S. ships visiting the port; however, in fog situations, the shallow areas and proximity of islands can make this a hazardous approach.

5.2.5 Inchon Typhoon Climatology

During the 27-year period June 1947 to October 1973, 36 typhoons approached to within a 180 n mi (333 km) radius of the Inchon harbor area. An average of one to two typhoons per year can therefore be expected to pose a strong wind threat to the harbor. Such a threat almost certainly will occur between the months of June to October with the peak threat most likely in August.

Of these 36 storms, only nine produced gale force winds (>33 kt) at Inchon and on no occasion did the maximum sustained wind exceed 50 kt.* This is probably due to the fact that typhoons are usually in the dissipating stage by the time they affect Inchon, with central wind speeds generally 45-60 kt. However, it should be noted that although storms may be in the dissipating stage and the majority will probably have recurved in their track orientation, a significant number of them will have recurved over mainland China and crossed the warm waters of the Yellow Sea to reintensify with, in some cases, recorded average wind speed increases of up to 20%. Although it is important to note these rare instances of storm intensification after recurvature, past history at Inchon suggests that wind speeds, even in such cases, will be substantially less than typhoon strength (<63 kt).

5.2.6 Typhoon Tracks and Local Topography

Inchon is well protected in all directions except the southwest by hills of 300-400 ft (91-122 m) (Figure 5-2). The tidal basin within the inner harbor is further protected from the northwest by the island of Wolmi Do, which rises to a maximum elevation of 194 ft (32 m). In assessing storm tracks and their implications at a particular point, it is important to remember that the variable nature of typhoon movement has resulted in a mean 24-hour forecast error of approximately 160 n mi (296 km) for those storms that have recurved.

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*Typhoon Carmen (1960) passed only a few miles to the west of Inchon producing southerly gusts of 68 kt, the highest observed in 36 years, and causing the loss of one ship.

The majority of storms (72%) that come within a 180 n mi (333 km) radius of Inchon make their approach from the southwest quadrant and then proceed either to the west or east of the city. The tendency has been for slightly more storms to take the easterly track past Inchon; in such cases, the counterclockwise circulation of the storm has produced northerly winds. The topographical protection afforded by the land masses to the north and northeast reduces the impact of such winds on the harbor area. Storms that pass to the west place Inchon in the "dangerous" semicircle and generally produce winds from the south. The general lack of topographical protection in this direction results in little modification of wind severity; the greater relative wind in this direction also produces higher wave action.

The maximum wave heights that can be expected with typhoon strength winds ($\geq$64 kt) in Inchon Harbor are given in Table 5-2.*

Table 5-2. Maximum wave heights that can be expected with typhoon strength winds ($\geq$64 kt) in the outer harbor (northern and southern part) and the tidal basin of Inchon.

Location	Outer Harbor		Tidal Basin (ft/m)
	Northern Part (ft/m)	Southern Part (ft/m)	
Winds generally from the north (tropical cyclone passage east of Inchon)	5/1.5	6/1.8	4/1.2
Winds generally from the south (tropical cyclone passage west of Inchon)	8/2.4	7/2.1	4/1.2

The implication that storm tracks to the west or east of Inchon will produce different effects in terms of adverse conditions has little practical significance for those ships facing a typhoon threat at Inchon. Examination of the small number of storms (8 out of 31) that have produced gale force winds during the years 1952-73 reveals that there is almost an equal chance of such winds with the easterly tracking storm as with the westerly tracking storm.

If it is assumed that topography will modify the severity of wind conditions for the easterly tracking storm, then it is reasonable to conclude that gale force winds are occurring well in advance of the storm's movement to the west or east of Inchon, and that the beneficial interplay of track and topography will often present itself downstream of the severest conditions.

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*Based on Forecasting Curves for Shallow-Water Waves from U.S. Army Coastal Engineering Research Center, 1973: Shore Protection Manual (Volume I).

Therefore, for all practical purposes, the severest conditions should be assumed for all typhoons forecast to affect the Inchon area and protective action should be taken.

5.2.7 Response to Typhoon Threats

There are three possible responses when typhoons are forecast to affect the Inchon area: remain in port within the shelter of the tidal basin; remain at anchor in the outer harbor; or evade at sea.

Remaining in port is only recommended when shelter in the tidal basin is available. The basin receives good protection from the surrounding topography and is protected from tidal fluctuations, and the maximum wave height that can be expected with typhoon strength winds is forecast to be only 4 ft (1.2 m). Remaining in the basin is also considerably more cost effective than evasion at sea. Figure 5-6 gives a recommended timetable for a move into the basin.

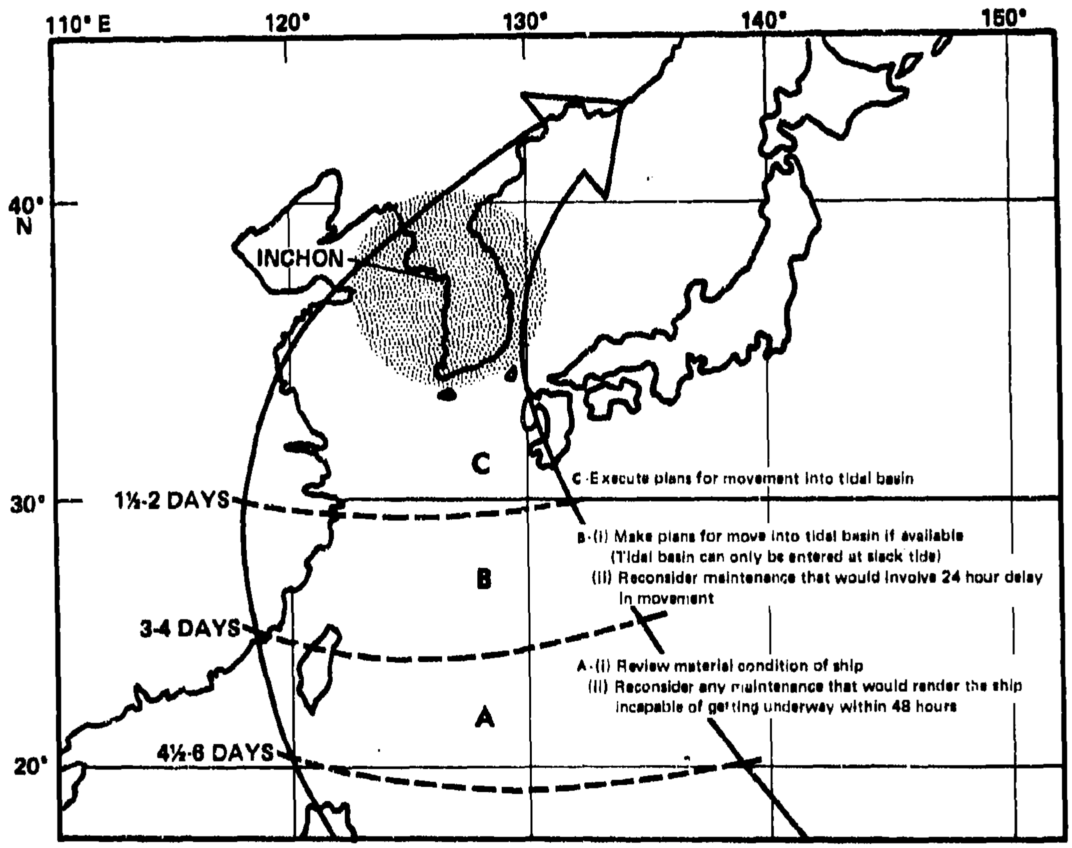

Figure 5-6. Typhoon threat timetable for Inchon.

If shelter in the tidal basin is not available, the alternative recommendation is evasion to the Yellow Sea. This is suggested in spite of the relatively modest winds that would be anticipated for a dissipating storm, for several reasons:

(1) Currents in the outer harbor may exceed 3 kt and currents of this magnitude have frequently been recorded at the anchorages.

(2) Holding action in the outer harbor is good only in the southern anchorages and these anchorages lie in a relatively confined north-northeast to south-southwest line.

(3) The high tidal range* coupled with a westerly tracking storm might result in a large peak surge with an anticipated large rise in the water level.

(4) The probable excessive congestion from small and medium boat traffic in the confined waters of the harbor would place restrictions on maneuverability.

(5) The relatively moderate wind speeds to be expected from a weakening storm system and the relatively rapid transit times after recurvature considerably reduce the hazard associated with evasion at sea.

The restricted waters near Inchon Harbor and the strong currents in the approach channels (generally around 2 kt in Tong Sudo channel, but as high as 8 kt at times in So Sudo Channel) make early evasion desirable. If evasion is delayed, later assessment of options can be based on the knowledge that storms affecting Inchon have generally produced winds $\geq$ 22 kt when north of latitude 35°N and winds $\geq$ 34 kt when north of 37°N. However, it should be remembered that given the strong currents and a steaming speed of 10 kt, it would require approximately six hours to clear the outer harbor and reach the open waters of the Yellow Sea. (Large vessels of the South Korean Navy sometimes anchor north of Taebu Do and Yanghung Do as an evasion procedure (Figure 5-2), but the proximity of land and the unfamiliar nature of the waters may make this an undesirable option for other vessels.) If other factors preclude the use of the tidal basin or make evasion at sea impossible, one of the southern anchorages in the outer harbor should be chosen. Under no circumstances should the northern A anchorages be utilized. The holding here is poor and at least one ship has run aground after dragging anchor. Annex H (Weather) to COMNAVFORKOREA/CTG-74.7 OPORD 201 (U) and Appendix 1 (Heavy Weather Doctrine) to Annex H of CINCPACFLT OPORD 201 (U) outline applicable doctrines and practices in heavy weather situations. For a more detailed evaluation of Inchon, Pusan and Chinhae as typhoon havens, see NAVENVPREDRSCHFAC Technical Paper No. 22-75.

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*Mean neap tidal range 11.4 ft (3.4 m); mean tidal range 18.8 ft (5.7 m); mean spring tidal range 26.2 ft (7.9 m); and maximum tidal range 32.3 ft (9.8 m).

5.3 PUSAN

5.3.1 General Port Description

Figure 5-7 shows the location of Pusan Harbor on the southeast coast at 35°06'N, 129°02'E.

Pusan Harbor, South Korea's principal deep water port, is divided by Yong-Do Island into well protected northern and southern harbors (Figure 5-8). Both harbors are further divided into inner and outer harbors. North Harbor accommodates ocean-going vessels while South Harbor is used primarily as a coastal shipping and fishing port. Unless otherwise stated, reference to Pusan Harbor will specifically apply to the North Harbor.

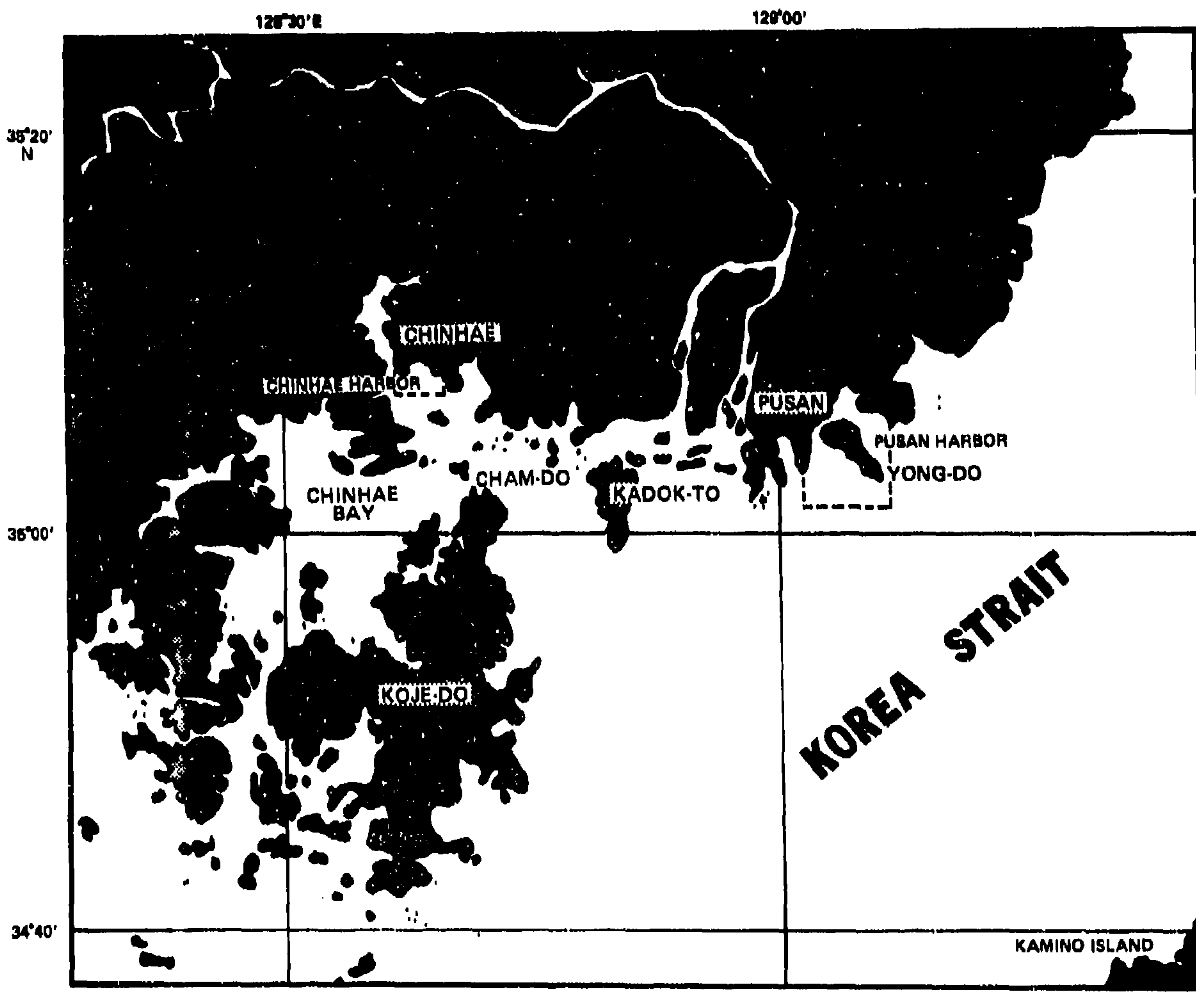


Figure 5-7. Locations of the ports of Pusan and Chinhae.

An intensive construction program is presently underway in the North Harbor to achieve a handling capability of 54 vessels at one time. This includes dredging of the fairway and construction of container and grain piers where indicated in Figure 5-8. Anchorages are available in the outer and inner harbors, and with the exception of a few rocky patches in the outer harbor, good anchor holding action is available in a mud and sand bottom. The inner harbor is one of the few in South Korea where deep draft vessels can berth at piers; it consists of four major piers, two quays and six deep draft anchorages.

The tidal range in Pusan Harbor is approximately 4 ft (1.2 m) at high tide. Springs are 3.9 ft (1.1 m) and neaps are 2.4 ft (0.7 m). Tidal currents are generally ½ kt, but can attain 3 kt at times in the channels between Yong-Do Island and Pusan Harbor.

For a detailed description of harbor facilities refer to CINCPACFLT Port Directory, Volume V, Section B1, or the Far East Port Directory, MSCFE Instruction 3170.4A, Section II-26.

5.3.2 Climatic Summary

Pusan Harbor is a fairly well protected, ice-free port that is generally not troubled by normal climatic elements other than threatening typhoon situations.

The strongest winds are generally from a northerly direction and although topographical protection to the north is generally good, a valley gap just east of north (Figures 5-8, 5-12) tends to act as a funnel to strengthen winds with a northerly component. During the winter months when northerly surface winds prevail, Pusan experiences winds often twice as strong as those observed at Taegu, which is located at the head of the Naktong basin. During periods of moderate to strong southerly winds, abnormal rises in sea level occur within the inner harbor; however, no major damage from this phenomenon has been reported except in the case of Typhoon Sarah (1959). Predominant wind directions at Pusan Harbor are shown by the monthly wind roses in Figure 5-9. A summary of climatic conditions for the Pusan area is given in Table 5-3.

5.3.3 Pusan Typhoon Climatology

During the 27-year period 1947-73, 57 typhoons passed within a 180 n mi (333 km) radius of Pusan and neighboring Chinhae. Such typhoon activity almost invariably occurs during the months of June through October, with the peak threat occurring in August. Analysis of wind data from 55 of the 57 storms revealed that 37 (67%) produced winds of $\geq$ 22 kt, and 16 (29%) produced winds $\geq$ 34 kt; in many cases, the winds $\geq$ 22 kt were recorded while the typhoons were still more than 300 n mi (556 km) from Pusan. The maximum sustained wind velocity recorded at Pusan was 70 kt in 1959, produced by Typhoon Sarah (see Para. 3.3.7). Moreover, gale force winds were found to have occurred in each month during the period June to October.

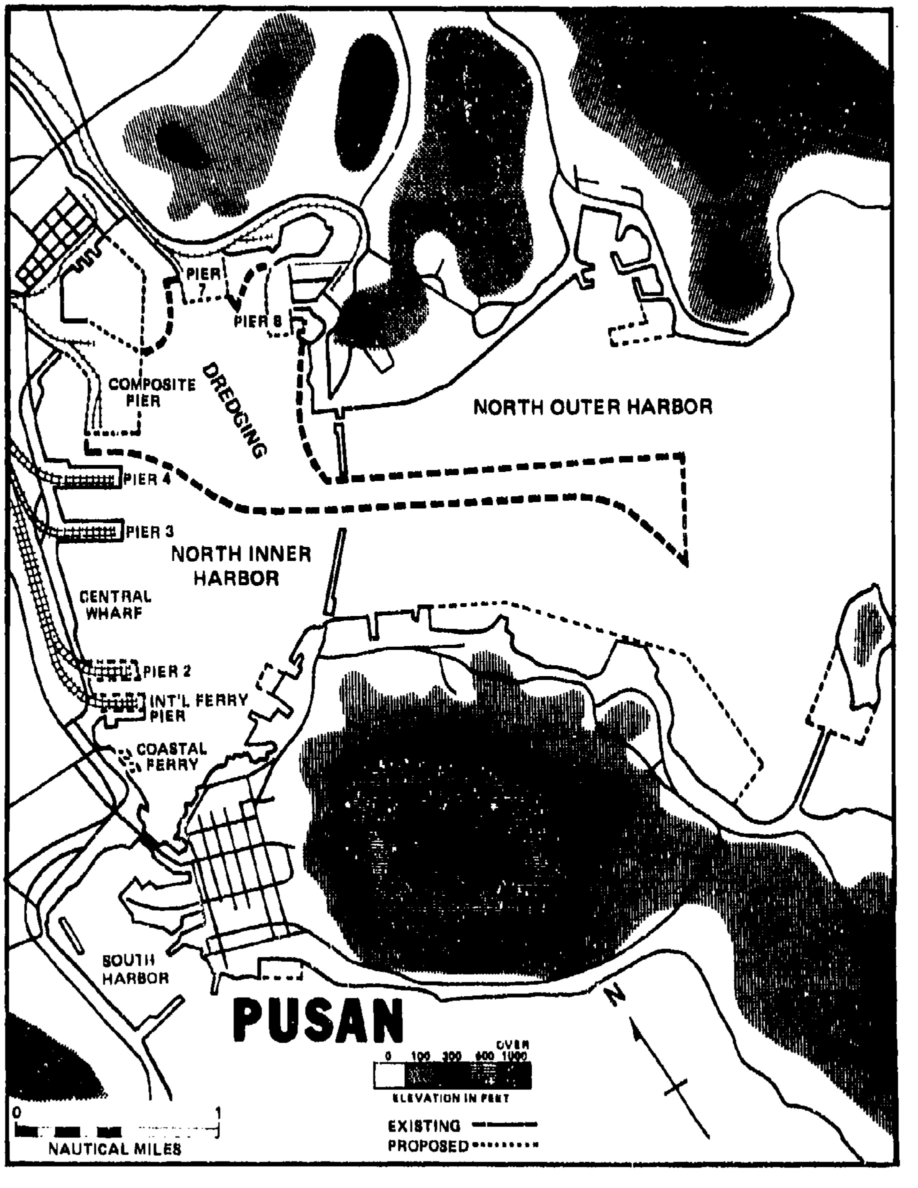


Figure 5-8. Pusan Harbor facilities.

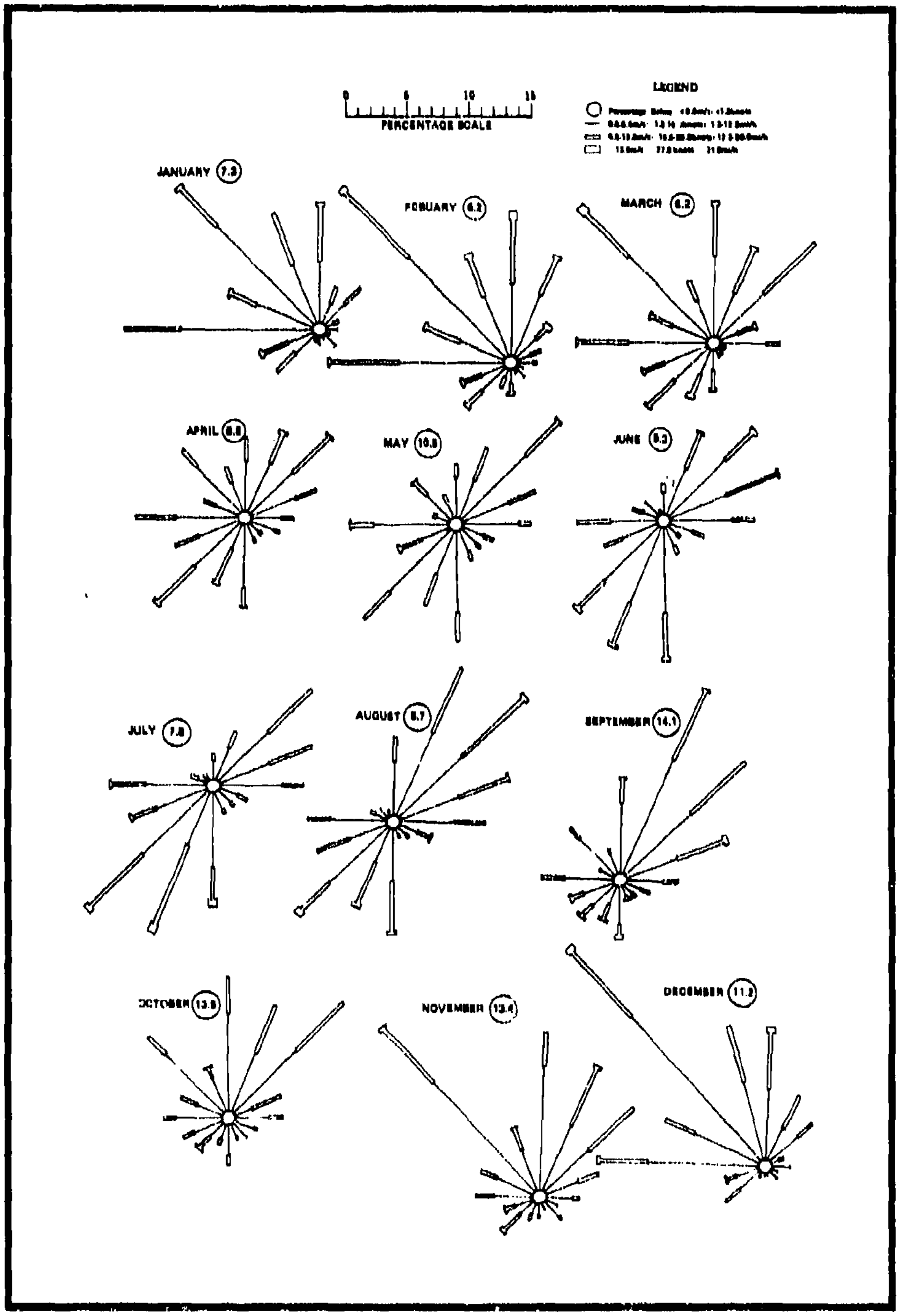


Figure 5-9. Monthly wind roses for the Pusan area (from Climatic Atlas of Korea, 1962).

Table 5-3. Climatic summary for the Pusan area.

Month	Air Temperatures °F					Relative Humidity %		Cloud Amount (0-10)		Rainfall		
	Mean			Extreme								
	Monthly	Maximum	Minimum	Maximum	Minimum	0600	1400	0600	1400	Average Amount (inches)	Number of days with rain 0.1 mm	Maximum in 24-hours (inches)
January	36	44	29	65	7	55	44	3.2	3.9	1.65	6.4	8.2
February	37	45	30	64	11	58	44	4.0	4.9	1.44	6.7	2.6
March	45	53	37	69	19	62	49	4.8	5.7	2.56	8.6	2.9
April	54	62	47	78	29	73	59	6.0	6.0	5.64	9.5	7.0
May	62	69	54	84	42	78	64	6.2	5.7	4.76	8.4	5.7
June	68	75	62	92	49	85	72	7.9	7.4	8.15	11.6	6.1
July	76	81	70	94	57	89	77	7.8	7.0	11.02	13.5	9.9
August	78	85	73	96	60	86	69	6.3	6.2	6.94	10.6	8.2
September	71	78	65	90	49	80	64	6.6	6.8	6.91	11.3	8.0
October	61	70	54	80	36	72	52	4.8	5.1	2.41	6.4	7.0
November	50	59	43	75	26	65	49	3.9	4.0	1.85	6.7	2.0
December	48	47	33	67	10	56	43	3.0	4.1	1.14	5.5	1.5
Mean	56	64	50	--	--	71	57	5.4	5 6	--	--	--
Total										54.47	104.2	
Extreme				96	7							9.9
Number of years	10-29	10-29	10-29	10-29		20				25		29

"Authorities: British Admiralty. South & East Coast of Korea Pilot, 3rd Edition, 1937. Met'l. Obs. Japan, Annual Report; Chelumpo Met'l. Observ. 1906-1920; Met'l. Obs. in Tyosen."

Table 5-3 (Continued)

Month	Wind											Average number of days with fog	Average number of days with gales	Average number of days with thunderstorms	Average number of days with snow
	Mean velocity (knots)	Maximum velocity (knots)	Percentage of Observations from												
			N	NE	E	SE	S	SW	W	NW	Calm				
January	8.51	37.51	36	8	2	0	1	2	11	38	2	0.4	7.1	0.1	2
February	8.34	36.29	36	7	2	2	2	3	11	35	2	0.5	4.7	0.1	3
March	7.55	39.25	27	10	6	5	6	7	13	24	2	0.6	4.7	0.3	1
April	6.60	40.98	23	11	10	8	10	9	12	14	3	1.3	2.2	0.5	0
May	5.64	54.36	17	10	11	10	12	11	13	12	4	2.5	0.6	0.6	0
June	5.04	24.84	15	12	12	15	14	9	8	8	7	3.2	0.5	0.7	0
July	5.82	38.03	11	11	11	13	18	14	11	6	5	3.3	0.7	0.9	0
August	5.64	31.43	19	16	12	11	13	9	8	6	6	0.6	0.6	1.4	0
September	5.99	41.59	32	20	10	6	5	5	5	13	4	0.2	0.6	1.2	0
October	5.99	30.65	39	16	5	4	2	3	7	20	4	0.1	1.2	0.5	0
November	7.03	37.69	34	8	2	2	2	4	13	32	3	0.4	2.9	0.2	0
December	8.34	35.17	37	7	2	0	0	2	11	39	2	0.4	6.1	0.1	2
Mean	6.71	--	27	11	7	6	7	7	10	21	4	--	--	--	-
Total												13.5	31.9	6.6	3
Extreme		54.36													
Number of years	25		29									20	15		15

Typhoons affecting Pusan will probably not be at the same advanced stage of dissipation as those affecting Inchon, although a large proportion do travel over the southwestern tip of Japan and lose some wind intensity by interaction with the land. Again, it is important to note that sea temperatures in the Yellow Sea and Sea of Japan during August are high enough to produce tropical cyclone intensification.

5.3.4 Typhoon Tracks and Local Topography

The harbor at Pusan is generally well protected by hills to the north, except to the north-northeast where the port opens up to a valley. To the southeast and southwest, there is little topographical protection. Of the tropical cyclones that passed within 180 n mi (333 km) of Pusan, 81% approached from a sector extending southwest-southeast. Of these, slightly more passed to the west than to the east. The topography of the harbor area is shown in Figure 5-10.

Because of the local topography, the strongest winds caused by a typhoon can be expected from the north-northeast, southeast and southwest. Southerly winds would be associated with a storm passing to the west and northerly winds with an easterly tracking storm.

Unlike Inchon, cyclones passing to the west of Pusan are much more likely to produce gale force winds than those passing to the east, but again, winds greater than 22 kt may be experienced when the storm is still 300 n mi (556 km) away. This fact, coupled with inherent forecast error, makes any option based on typhoon track of limited practical significance to the ship facing a typhoon threat.

Wave action in Pusan's north inner harbor is minimal due to the short fetch. The north outer harbor presents a fetch of about 100 n mi (185 km) for winds out of the southeast; therefore, high wave action can be expected if winds are from this direction (see Table 5-4).

Table 5-4. Maximum wave heights that can be expected with typhoon strength winds ($\geq$ 64 kt) in north outer and inner harbor (based on relationships extracted from U.S. Army Coastal Engineering Research Center, 1973).

Location	North Outer Harbor (ft/m)	North Inner Harbor (ft/m)
Winds generally from the north (tropical cyclone passage east of Pusan)	4/1.2	5/1.5
Winds generally from the south (tropical cyclone passage west of Pusan)	12/3.6	4/1.2

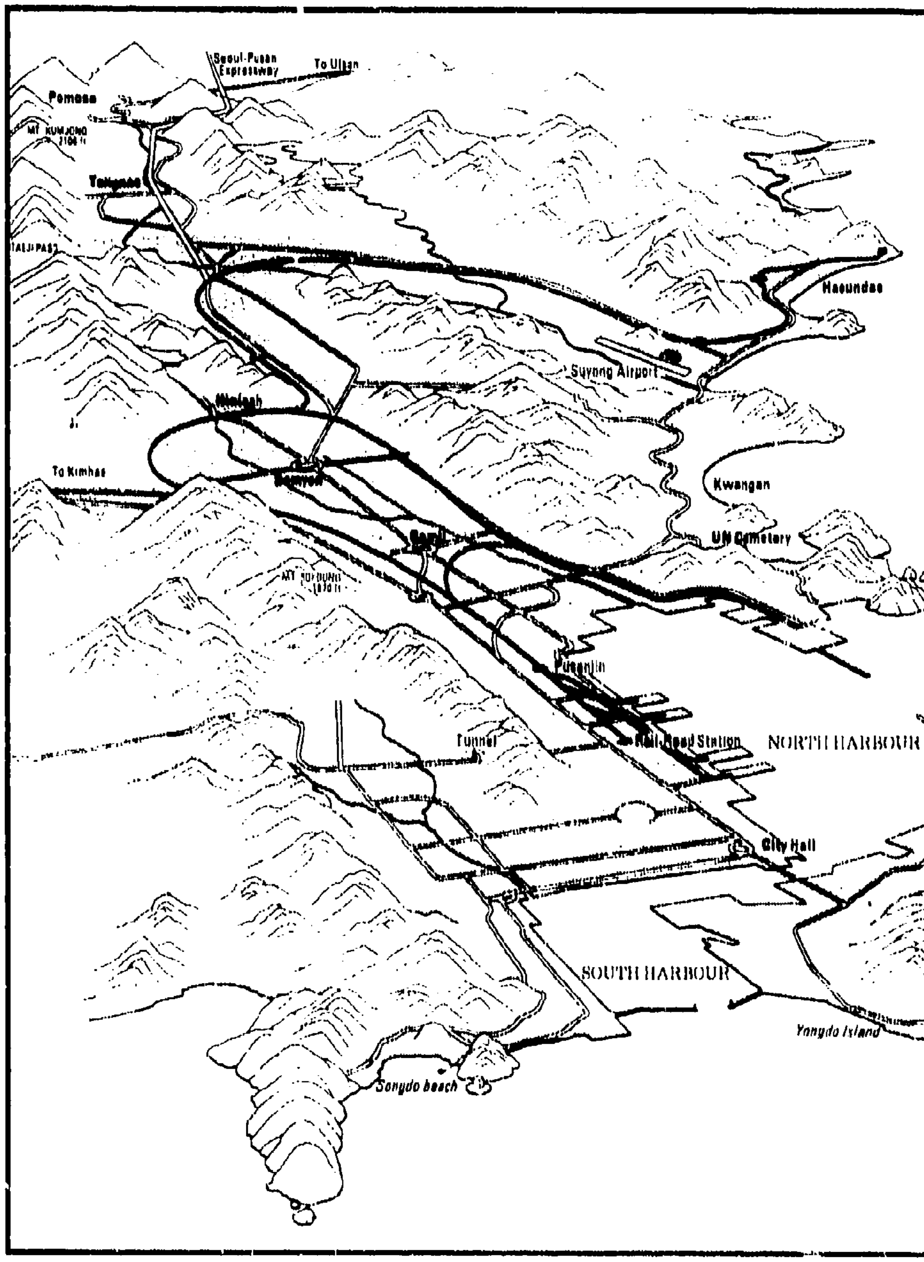


Figure 5-10. Topography of the Pusan Harbor area (after Bartz, 1971).

5.3.5 Response to Typhoon Threats

Of the two possible responses -- remaining in port or evasion at sea -- evasion at sea is recommended for all U.S. Navy ships at Pusan for the following reasons:

(1) North inner harbor has little protection from northerly winds; in addition, northerly winds may intensify from funneling effects of the valley opening to the north-northeast.

(2) North outer harbor is exposed to southeasterly winds and the large fetch to southeast may produce 12 ft (3.6 m) wave heights.

(3) The surge effect present at high tide can be dangerous.

With evasion from Pusan Harbor as the preferred course, the following evasion tactics are recommended:

Evasion to the Sea of Japan. This route takes the ship to higher latitudes where the intensity of the tropical cyclone decreases markedly. The Sea of Japan provides ample maneuvering room to place the ship in the navigable or "safe" semicircle of the tropical cyclone. This evasion route also allows a vessel to cross to the Pacific Ocean from the Sea of Japan by means of the Tsugaru Strait between the southern tip of Hokkaido and the northern tip of Honshu.

It should be remembered when considering this tactic that the tropical cyclone probably will overtake the ship since the storm's speed is often in excess of 30 kt once it enters the Sea of Japan. However, at the same time, the intensity of the tropical cyclone decreases as it reaches the more northerly latitudes and the effects of the associated wind and sea will be much less intense than if the tropical cyclone is met at lower latitudes.

Evasion to Chinhae Bay, north of Koje Do. This is the evasion tactic used by the larger South Korean Navy ships and it is recommended if a vessel must remain in Korean waters. Chinhae Bay is a large, landlocked bay formed by the northwest side of Koje Do and the mainland. The bay is entered from the east through the deep passage on either side of Chan Do. The bottom of the bay is predominantly mud and shell and provides a good anchor holding action. Protection from strong winds is available in the bay for winds from all directions.

The only available reports of damage from ships in Chinhae Bay during a typhoon were associated with Typhoon Sarah in 1959. This storm passed approximately 10 n mi (19 km) to the west of Pusan with central winds in excess of 90 kt. Several vessels ran aground in Chinhae Bay because they were not properly anchored, but the damage to Pusan Harbor was much more severe.

Other Routes. Alternate courses of action for evasion at sea may be developed by the use of FWC/JTWC warnings, mean tropical cyclone tracks, track limits, and average speed of movements for the months of June-October.

Evasion must be considered at the earliest opportunity. Based on information provided by FWC/JTWC, sortie plans should be executed no later than when the storm is within 1½ days of the Pusan area.

Annex H (Weather) to COMNAVFORKOREA/CTG-74.7 OPORD 201 (U) and Appendix 1 (Heavy Weather Doctrine) to Annex H of CINCPACFLT OPORD 201 (U) outline the doctrines and practices in heavy weather situations. For a more detailed evaluation of Inchon, Pusan and Chinhae as typhoon havens, see NAVENVPREDRSCHFAC Technical Paper No. 22-75.

5.4 CHINHAE

5.4.1 General Port Description

Chinhae Harbor, located at 35°08'N, 128°41'E on the southeast coast of the Korean Peninsula (Figure 5-11), is the site of South Korea's principal naval base. The port of Pusan is less than 20 n mi (37 km) due east.

Chinhae, selected as a naval base in 1905 and designated an important port by the Japanese in 1916, became the headquarters of the South Korean Coast Guard in 1945 and a naval base in 1949. It is also the site of the South Korean Naval Academy and war colleges.

The harbor has four piers and four quays that are used by South Korean Navy ships. The usual berth for visiting ships is a quay constructed of stone and concrete, designated Pier 2. Pier 2 has two distinct berths with a depth of 25 ft (7.6 m) at mean low tide.

Within the harbor, 24 mooring buoys (reserved for the South Korean Navy) and 39 anchorages (all in 5-6 fathoms (9-11 m) of water) are available. Anchorages Z-1 and Z-2 are normally assigned to U.S. Navy ships. The tidal range in the harbor is 6-8 ft (1.8-2.4 m) and tidal currents of 1½ kt can be expected in the approach channel.

Chinhae Harbor's topographical protection from winds is depicted in Figure 5-11 and described in Para. 5.4.4 below.

For a more detailed description of harbor facilities, refer to CINCPACFLT Port Directory, Volume V, Section B2.

5.4.2 Climatic Summary

Chinhae, like Inchon and Pusan, is an ice-free harbor. Local weather and wind conditions are summarized in Figure 5-12.

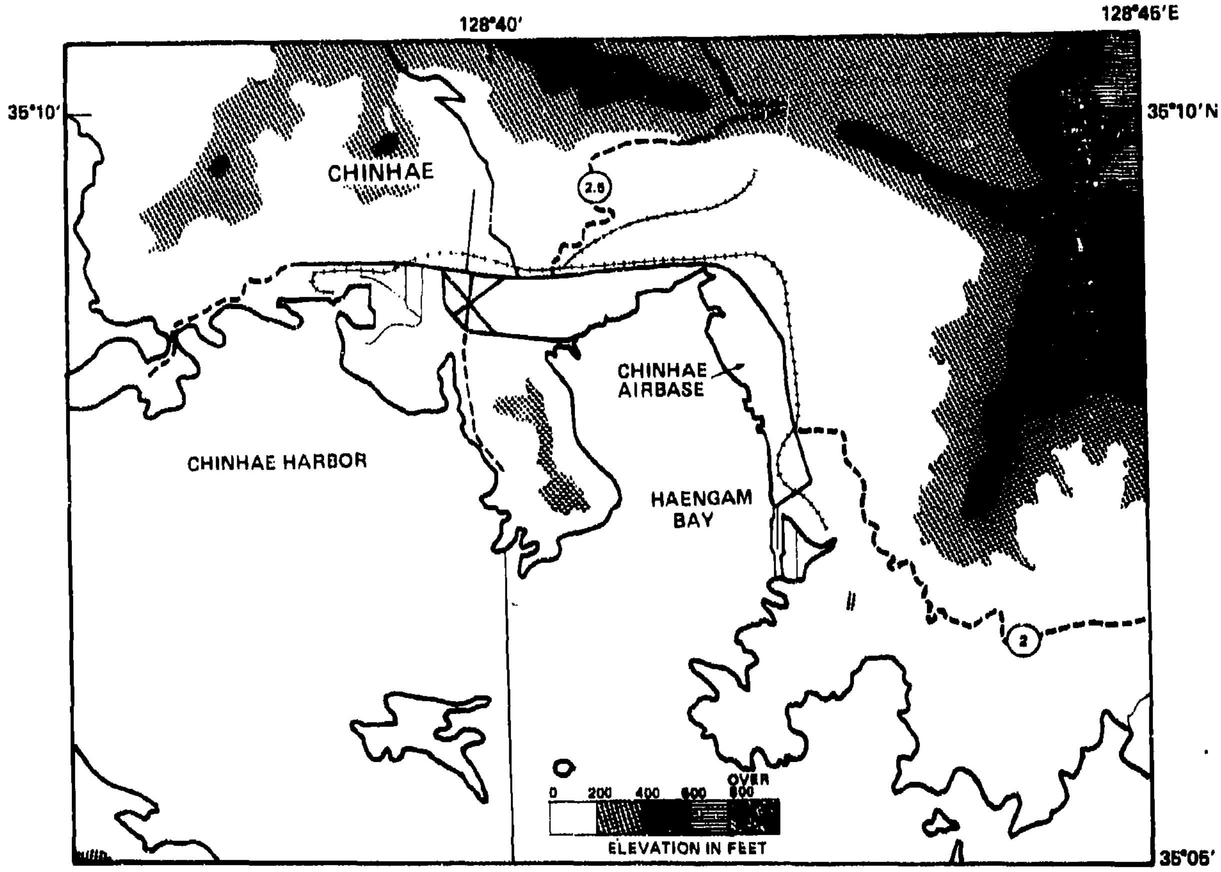
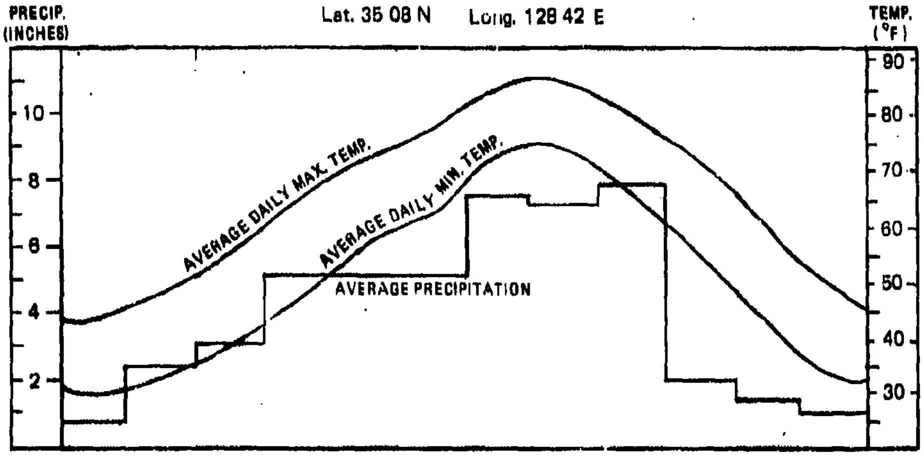


Figure 5-11. Geography and topography of the Chinhae Harbor area.

CHINHAE, KOREA

Elev. 10'

Lat. 35 08 N Long. 128 42 E



MEAN NUMBER OF DAYS WITH PRECIPITATION, THUNDERSTORMS, FOG

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	3	4	5	9	7	9	13	9	11	4	3	2
	0	0	0	0	<1	<1	1	1	1	<1	0	<1
≡	6	7	9	13	12	14	20	17	12	8	8	8

TOTAL PRECIPITATION / SNOWFALL (INCHES)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
•	0.62	2.30	3.12	5.44	5.42	5.40	7.66	7.34	7.95	2.03	1.55	1.20
*	0.8	0	0	0	0	0	0	0	0	0	0	1.2

MEAN RELATIVE HUMIDITY (PERCENT)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
62	62	66	72	75	80	85	81	78	69	68	65

MEAN TEMPERATURE (°F)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
35	39	46	55	64	70	78	80	72	63	52	41

ABSOLUTE MAXIMUM/MINIMUM TEMPERATURE (°F)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
62	63	68	80	89	93	94	96	97	83	88	70
11	13	20	32	45	51	62	62	51	35	23	16

PREVAILING WIND DIRECTION / MEAN SPEED (KNOTS)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
NW	NW	NW	SW	SSW	SSW	SW	NE	NE	NE	NW	NW
6	6	5	5	4	4	4	5	4	5	5	5

Figure 5-12. Summary of monthly climatic data for Chinhae.

5.4.3 Chinhae Typhoon Climatology

During the period 1951-61 when wind observations were taken at Chinhae Air Base, 21 tropical cyclones were found to have affected Chinhae by passing within a 180 n mi (333 km) radius of the harbor area. Of these, only 33% produced winds of greater than 22 kt and only 24% produced gale force winds of greater than 34 kt. The data base for these figures is small, however, and it should be remembered that typhoons as far away as 340 n mi (630 km) may produce winds greater than 22 kt at Chinhae. Gale force winds during this reporting period occurred only during August and September. Winds of 34 kt generally did not begin until the storms reached 33°N. Typhoon Sarah (1959) produced maximum winds from the northeast of 55 kt, but their effects on Chinhae were probably considerably modified by the high ground to the northeast.

5.4.4 Typhoon Tracks and Local Topography

Chinhae Harbor is well protected by hills on all sides except where it faces the ocean to the south and southeast. Hills on the island of Koje Do do offer some protection to the south, however, so it is only to the southeast that there are no barriers to the wind (Figure 5-11).

Southeasterly winds would therefore produce the greatest threat within the harbor and could be expected to arise from storms tracking to the west of Chinhae. It is generally felt that the most severe threat will occur when a cyclone approaches from the southwest and passes within 30 n mi (56 km) to the west of Chinhae.

5.4.5 Response to Typhoon Threats

Of the two conceivable options -- remaining in port or evasion at sea (either open sea or a confined sheltered area) -- neither seems irrefutably supported by available data or past experience. Remaining in port when possible is usually a preferred option because of its cost effectiveness compared to evasive steaming at sea. At Chinhae, the analyses of typhoon threats over the 11-year period 1951-62, as well as experience dating further back, indicate that remaining in port would be a reasonable choice in most cases. However, complete support for this option is denied by the experience of Typhoon Sarah (Para. 3.3.7), which passed just 10 n mi (18.5 km) to the east of Chinhae with central wind speeds of 90 kt. The topography around the harbor helped to reduce local wind velocities substantially, but the sustained northeasterly winds of 55 kt were still sufficient to cause a number of South Korean Navy vessels to run aground and sustain damage. (The potential hazard in this situation was somewhat reduced by the easterly track. If the storm track had been just a little further west to produce more severe conditions of wind and sea, the consequences would have been much more serious for ships remaining in port.)

There is insufficient typhoon data to dictate with confidence the wind strength ceilings that would determine alternative courses of action. However, based on the experience of Typhoon Sarah and in the absence of data on any other extreme case, it would seem prudent to seek the more secure shelter of Chinhae Bay for forecast wind intensities greater than 80 kt. For more intense storms, forecast intensity > 110 kt, an evasive route into the Sea of Japan is recommended. For ships larger than destroyer size, remaining in the harbor is not recommended in any typhoon threat situation.

Annex H (Weather) to COMNAVFORKOREA/CTG-74.7 OPORD 201 (U) and Appendix 1 (Heavy Weather Doctrine) to Annex H of CINCPACFLT OPORD 201 (U) outline the doctrine and practices in heavy weather situations. For more detailed evaluation of Inchon, Pusan and Chinhae as typhoon havens, see NAVENVPREDRSCHFAC Technical Paper No. 22-75.

5.5 FISHING ACTIVITIES

The abundance of fish in coastal waters has provided a major source of food for the people of South Korea. The fishing industry was almost devastated by the Korean Conflict, but recovered quickly to reach production figures of 933,000 tons by 1970. By 1981, current long range plans call for a fish catch of 3,140,000 metric tons with a fleet of 800 distant-water vessels.

The currents around the Peninsula provide temperature conditions suited to a great variety of fish. The eight major species are squid, saury pike, Alaska pollock and shrimp from east coast fishing operations; yellow corvina (chogi), sabre fish, mackerel and anchovies from west coast operations; and all of these except pollack from the south coast. The convergence of the warm Tsushima Current and the colder Liman Current provides a favorable environment for many fish species (including saury, which is heavily exploited by the Japanese fishing industry). Examination of DMSP VHR infrared nighttime data (Figure 5-13; Fett, 1975) shows the warmer, darker-shaded water intruding well into the Sea of Japan and its zone of mixing with the lighter-shaded cold water.

Figure 5-14 shows the corresponding nighttime visible image with the lights of Seoul and Pusan clearly visible. A large concentration of lights within the Sea of Japan is also visible near the zone of convergence of the warm and cold waters; these are the searchlights and high-powered incandescent lamps commonly used by fishing vessels to attract schools of saury.

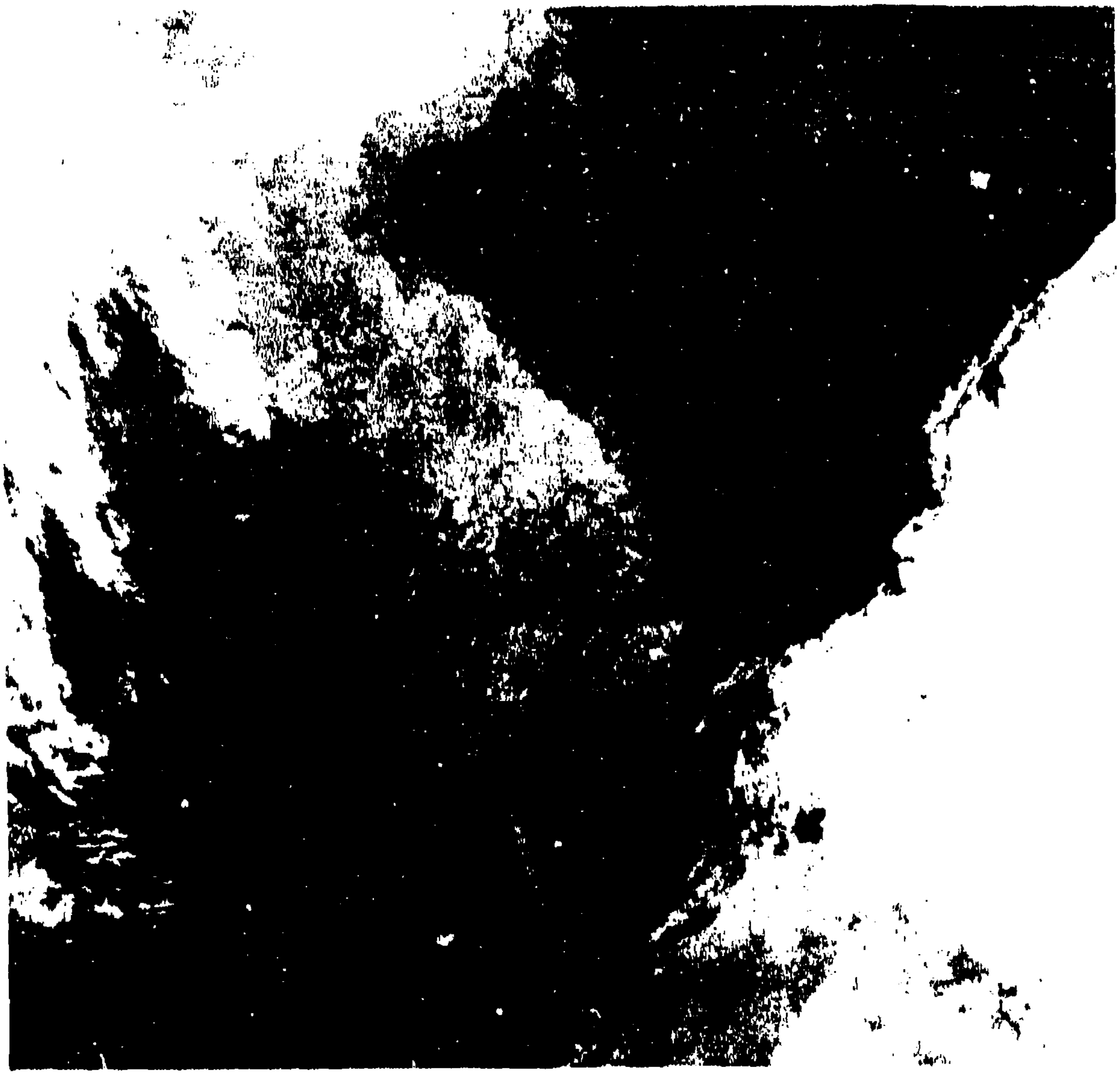


Figure 5-13. DMSP VHR IR nighttime image of the Korean Peninsula, 26 Sep 74, 1555Z.

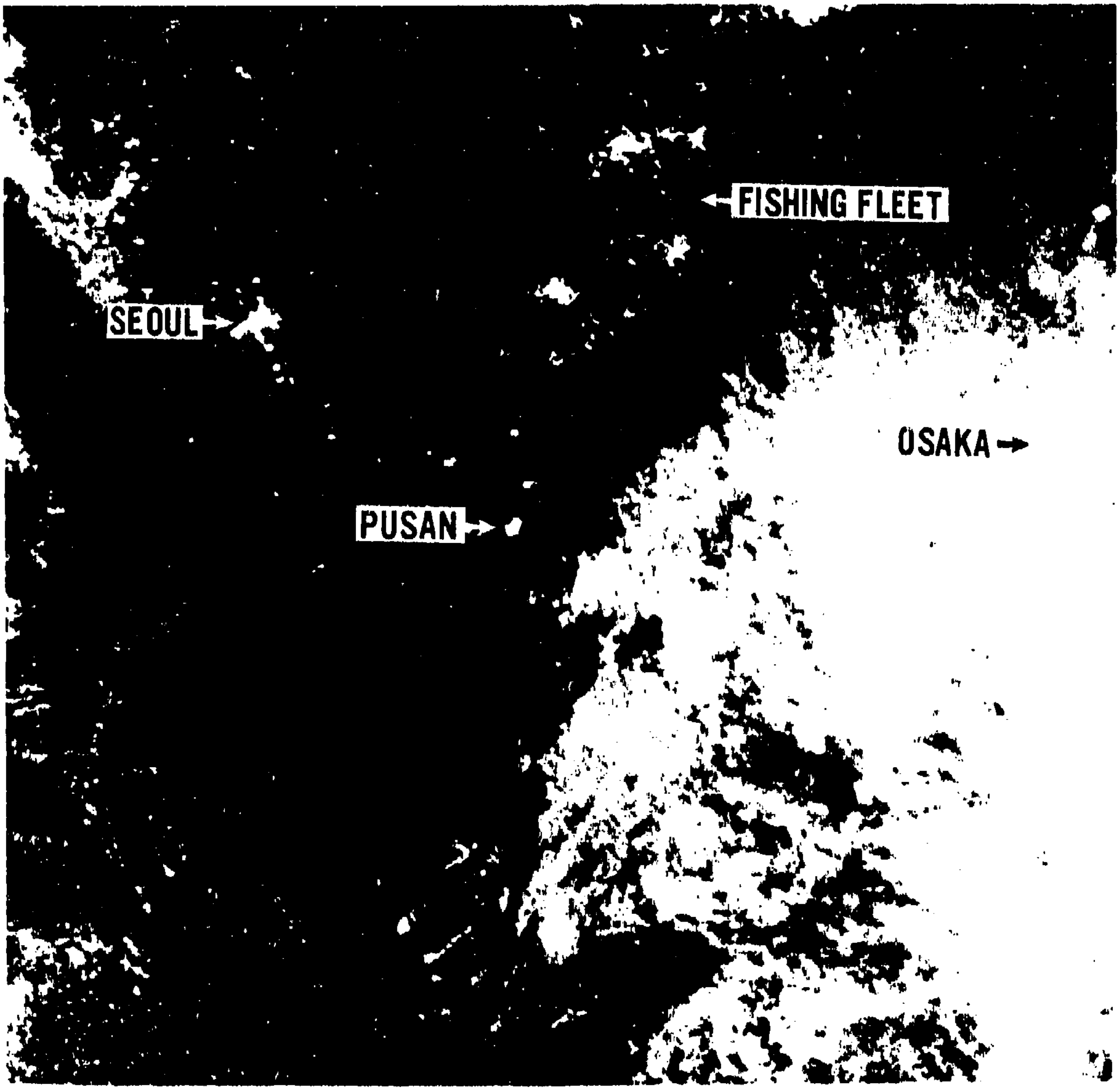


Figure 5-14. DMSP VHR visible nighttime image of the Korean Peninsula, 26 Sep 74, 1555Z.

Of the 70,000 fishing boats around South Korea, the majority are small wooden vessels. However, increasing numbers of larger distant-water and motorized vessels are appearing. The decline in catches around the coasts during the late 1960's encouraged more expansion into distant-water fishing and the South Koreans began fishing outside their own coastal waters for the first time. They moved into the Bering Sea where the convergence of the Alaska Stream extension water and the Bering boreal cold water provided a favorable area for cod and Alaska pollock.

By the end of 1972, the distant-water fleet had expanded to 369 vessels including 298 tuna longlines, 60 stern trawlers and 8 transports. By 1977, the distant-water fleet included a 20-boat skipjack tuna fleet to operate in the central Pacific. The inshore vessels are mainly of traditional design, 60-80 ft (18-24 m) in length, and most operate close to the coast all around the Peninsula. Some newer vessels 100-200 ft (30-60 m) in length have been built for nighttime mackerel and chogi fishing.

Off the west coast, fishing in the Han-Imjin estuary is prohibited and under strict surveillance in the sector from Paengyang-do east to Kanghwa Island. The two major distribution centers on this coast are Inchon and Kunsan. Major concentrations of small vessels are found in the squid fishing areas (usually at night) where the fishing boats remain stationary while taking the catch.

On the east coast, the northern limit of fishing has been drawn back to 22 n mi (12 km) south of the military demarcation line. In the Joint Fishery Zone offshore, the Joint Fishery Commission closely regulates quotas, tonnage and equipment. The major fishing center on this coast and in the whole of South Korea is Pusan, which is the base port for all distant-water vessels and the location of the Pusan fisheries college. Of the 20,000 vessels a year which enter Pusan, 75% are coastal and fishing vessels.

There are now 20 recognized fishing ports in South Korea, compared to 9 in 1957, which gives further indication of the buildup of fishing fleet activities around the Peninsula and in distant-water fishing areas.

5.6 SHIPPING TRAFFIC

Routes of warships are generally classified; the major commerical shipping lanes are shown in Figure 5-15. Although increasing at a dramatic rate, the distant shipping traffic is still relatively light at 10 million tons or less annually for the routes shown.

Assuming that the typical vessel carries 10,000 tons and travels at 20 kt, an average of only three ships per day pass any given point at a spacing of approximately 150 n mi (278 km). However, this approximate figure is likely to increase rapidly and steadily as South Korea develops its industries and increases exports.

Coastal shipping is extremely heavy. A primary cause is the very substantial fishing industry operating from 20 recognized fishing ports and the relative ease of transporting industrial products from the east to west coasts by sea rather than across the mountainous interior.

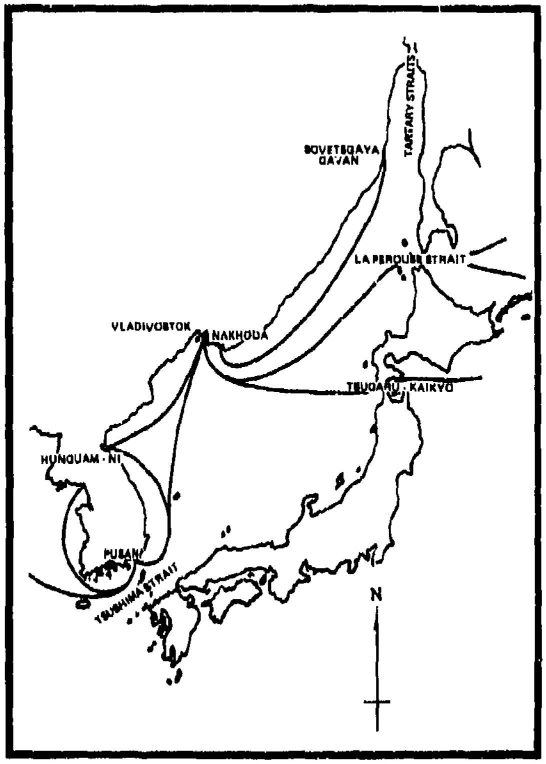


Figure 5-15. Shipping lanes around the Korean Peninsula and through adjacent sea areas (all 10 million tons or less annually).

SECTION 6

CONTENTS

6. SOUTH KOREAN METEOROLOGICAL NETWORK

6.1 INTRODUCTION

The South Korean meteorological network, headquartered at the Central Meteorological Office in Seoul, serves both the general public and civil aviation interests. Figure 6-1 shows major-station locations; Table 6-1 lists all stations in the network and defines the types of data provided by each station. There is also a large military environmental network. The South Korean Air Force, with a forecast center at Taegu, supports Korean Air Force and Army units, and a small forecast center at Chinhae supports naval needs. The U.S. Air Force supports American military units within South Korea, and Fleet Weather Central Guam has area responsibility for supporting U.S. Navy ships operating in the area. Table 6-2 lists the types of forecasts issued by military stations and indicates whether they are operated by USAF or South Korean personnel.

6.2 THE U.S. MILITARY ENVIRONMENTAL NETWORK

The U.S. Air Force provides forecasting support through detachments of the 20th Weather Squadron based at Yongsan, Seoul (Det. 18), Kunsan (Det. 10) and Osan (Det. 15). Osan is a location for a DMSP (Defense Meteorological Satellite Program) direct readout facility.

For forecast purposes, the USAF divides South Korea into several geographical areas (see Figure 4-6 in Section 4); 24-hour forecasts for these areas are issued daily. Navy forecasts are issued routinely on the Fleet broadcast by FWC Guam, which provides 12-hour plain language forecasts covering the Sea of Japan, Yellow Sea and East China Sea. An individually tailored 24-hr forecast of weather and sea conditions (WEAX) can be obtained on request from FWC Guam by ships not carrying meteorological personnel. Generally all that is necessary to obtain this service is the addition of WEAX to the end of line 1 of the ship's MOVEREP.

Other services available on request from FWC Guam include surf forecasts for particular beach areas; SHARPS (Ships Helicopter Acoustic Range Predictions); ASRAPS (Antisubmarine Range Predictions); vertical and horizontal thermal profiles; and underwater sound propagation forecasts for given areas. In typhoon threat situations, the Joint Typhoon Warning Center (JTWC), Guam, routinely issues tropical cyclone/typhoon warnings. Additionally, those ships operating in the South Korean area out of Yokosuka Naval Base Japan, can obtain support/advice from the U.S. Naval Weather Service Facility, Yokosuka (Ext. 7546).

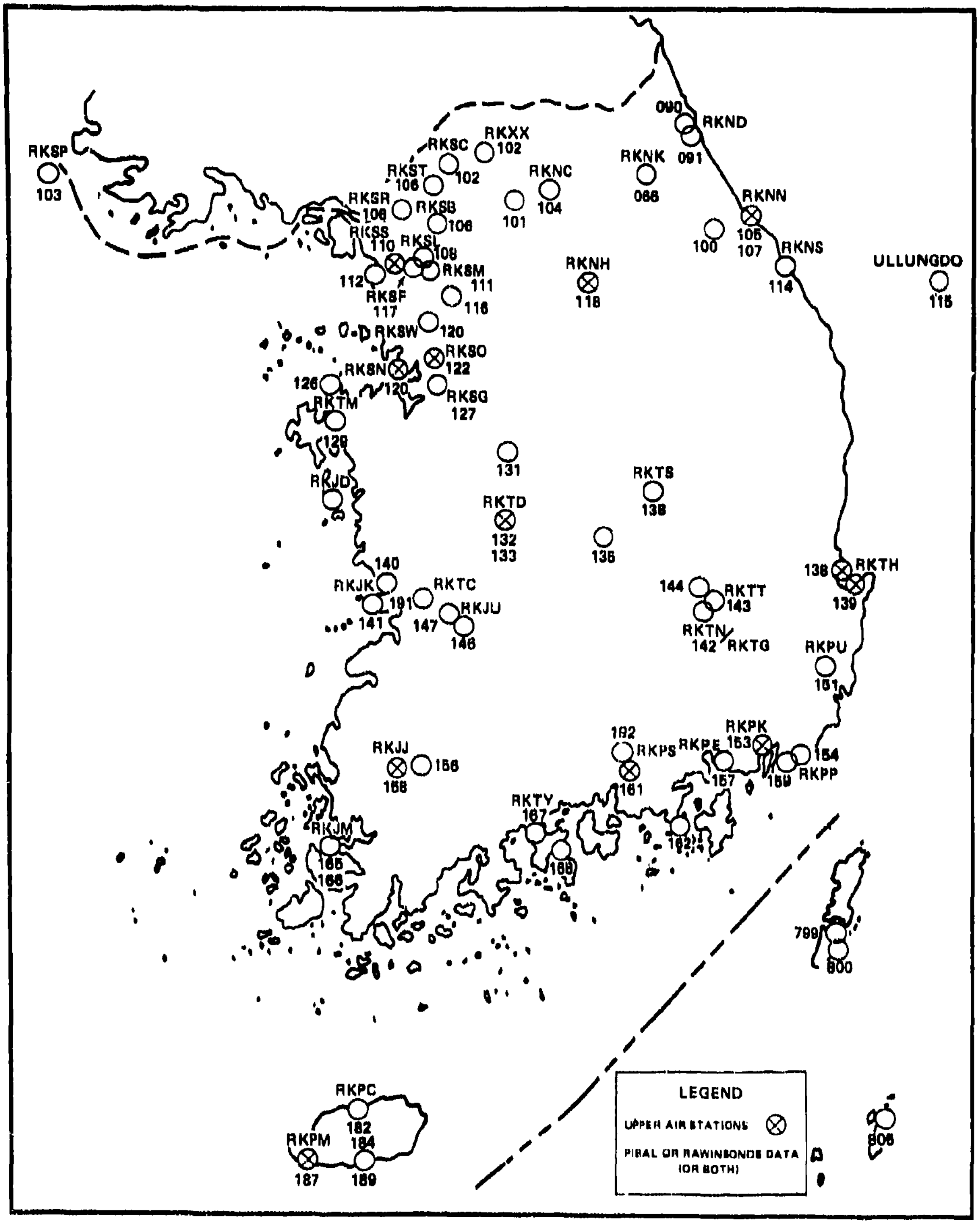


Figure 6-1. Locations of major stations in the South Korean meteorological network (after 1st Weather Wing, USAF).

Table 6-1. South Korean meteorological network observing stations and types of data provided.

BLKSTN	CALL LTRS	STATION NAME	DATA TYPES*	SFC LAT	SFC LONG	SFC ELEV
47003		WOON-GI	I M	4219N	13024E	0089
47008		CHONG-DZIN	I M	4147N	12949E	0090
47014		DZOONG-GANG	I M	4147N	12653E	0313
47016		HYESAN	I M	4124N	12813E	0998
47020		KANGE	I M	4058N	12636E	0305
47025		KIM CHAIK/SONGUIN	I M	4041N	12913E	0046
47035		SIN-EUZOO/SINUUIJO	I M	4006N	12423E	0008
47041		HAMHEUNG	I M	3954N	12731E	0034
47055		WONSAN	I M	3911N	12726E	0037
47058		PYONGYANG	I M R	3901N	12549E	0016
47061		CHONGJIN		3844N	12811E	0034
47063		SINMAK		3825N	12614E	0024
47065		SARIWON	I M	3831N	12546E	0024
47066	RKNK	HYUN-NI/R-420	T	3757N	12819E	0274
47069		HAIZOO	I M	3802N	12542E	0081
47070		KAISONG	I M	3758N	12633E	0060
47090		SOGCHO	I M	3812N	12836E	0007
47091	RKND	SOGCHO ARPT		3808N	12836E	0009
47100		TAEKWANLYUNG		3741N	12844E	0830
47101		CHUN CHON	I M	3752N	12744E	0075
47102		CHONGONG-NI/A-228		3802N	12709E	0070
47102	RKSC	CAMP SANTA BARBARA (USAF)		3802N	12709E	0069
47102	RKXX	NIGHTMARE RANGE (USAF)		3804N	12721E	
47103	RKSP	PACKLYUNGDO AB PYDO	T P	3758N	12440E	0177
47103	RKSE	PY-DO BEACH		3757N	12443E	0002
47104	RKNC	CHUN CHON/A-306 (USAF)	T	3752N	12743E	0076
47105		KANGNUNG	I M	3745N	12854E	0026
47106	RKSB	UIJONGBU/A-210 (USAF)	T	3744N	12703E	0053

*DATA TYPES

I = 3 hourly synoptic
M = 6 hourly synoptic
T = Metar
R = RAOB
P = Pibal
A = Forecast - TAF
D = Radar

(SFC ELEV in meters above MSL)

Table 6-1 (Continued)

BLKSTN	CALL LTRS	STATION NAME	DATA TYPES*	SFC LAT	SFC LONG	SFC ELEV
47106	RKSR	SINSAN NI/A-112 (USAF)	T	3747N	12651E	0024
47106	RKST	TONG DU CHON/A-220 (USAF)	T	3755N	12703E	0060
47107	RKNN	KANGNUNG AB	T P A D	3745N	12857E	0006
47108	RKSL	SEOUL CITY	I M	3734N	12658E	0086
47110	RKSS	SEOUL KIMPO INTL	T P A D	3733N	12648E	0018
47110	RKSY	YONGSAN/H-201 HP (USAF)	T	3731N	12700E	0015
47111	RKSM	SEOUL AB	T A	3726N	12707E	0020
47111		SEOUL/YONGDUNGPO		3731N	12655E	0100
47111	RKSH	TANGO COMMAND CENTER (USAF)		3725N	12704E	0020
47112		INCHON	I M	3729N	12638E	0069
47113	RKSA	ASCOM CITY/A-102 (USAF)		3730N	12642E	0018
47114		SAMCHUK ARPT		3730N	12908E	0003
47115		ULLUNGDO ISL. (FL)	I M	3729N	13054E	0221
47116		KWANAKSAN	D	3727N	12658E	0629
47117	RKSF	SEOUL/YONGDUNGPO	T	3730N	12656E	0046
47118	RKNH	HOENGSUNG/R-401	T P A	3726N	12757E	0101
47119		SUWON	I M	3716N	12659E	0037
47120	RKSW	SUWON AB	T A	3715N	12700E	0024
47120	RKSN	KOON-NI RNG (USAF)	T P A	3702N	12645E	0012
47120	RKSK	SUSAEK AIRPORT		3736N	12652E	0014
47122	RKSO	OSAN AB (USAF)	T R P A D	3706N	12702E	0011
47126	RKTM	MANGILSAN AB	T	3656N	12627E	0302
47127	RKSG	PYONGTAEK/A-511 (USAF)	T	3657N	12702E	0014
47129		SEOSAN	I M	3647N	12627E	0021
47131		CHONGJU	I M	3638N	12726E	0059
47131	RKSU	YEO JU RNG	T	3726N	12738E	0043
47132	RKTD	TAEJON AB	T P A	3620N	12723E	0064
47133		TAEJON	I M	3618N	12724E	0077
47135		CHUPUNGNYONG	I M	3613N	12800E	0246
47138		POHANG	I M R P	3602N	12923E	0006
47138	RKTS	SANGJU	T	3625N	12819E	

*DATA TYPES

I = 3 hourly synoptic   M = 6 hourly synoptic
T = Metar   R = RAOB
P = Pibal   A = Forecast - TAF
D = Radar
(SFC ELEV in meters above MSL)

Table 6-1 (Continued)

BLKSTN	CALL LTRS	STATION NAME	DATA TYPES*	SFC LAT	SFC LONG	SFC ELEV
47139	RKTH	POHANG AB	T P	3559N	12925E	0020
47140		KUNSAN	I M	3559N	12642E	0026
47140	RKJU	JHUNJU/CHONJU		3552N	12707E	0029
47141	RKJK	KUNSAN AB	T A D	3555N	12637E	0010
47142	RKTN	TAEGO AB/TONCHON	T A	3554M	12839E	0037
47142	RKTG	TAEGO SOUTH/A-805	T	3550N	12835E	0070
47143	RKTT	TAEGU ARTCC	I M	3553N	12837E	0058
47143	KOKF	TAEGU FOCUS LENS CP	I M	3553N	12837E	0061
47144		TAEGU AGRIMET		3557N	12833E	0055
47146		CHUNGJU	I M	3549N	12709E	0051
47147	RKTC	CHUNJU AIRPORT		3553N	12707E	0030
47151	RKPU	ULSAN ARPT		3535N	12921E	0010
47152		ULSAN	I M	3533N	12919E	0010
47153	RKPK	PUSAN/KIMHAE	I P A D	3511N	12856E	0004
47154	RKPP	PUSAN INTL ARPT	T A	3510N	12908E	0002
47156		KWANGJU	I M	3508N	12655E	0071
47157	RKPE	CHINAE/R-813	T	3508N	12842E	0004
47158	EKJJ	KWANGJU	T P A	3507N	12649E	0013
47159		PUSAN	I M	3506N	12902E	0069
47161	RKPS	SACHON AB	T P A	3505N	12895E	0008
47162		CHUNGMU	I M	3450N	12826E	0040
47165		MOKPO/YONG DANG	I M	3447N	12623E	0053
47166	RKJM	MOKPO AIRPORT		3445N	12622E	0003
47167	RKJY	YOSU AIRPORT		3450N	12737E	0017
47168		YOSU	I M	3444N	12744E	0067
47182	RKPC	CHEJU INTL	T A	3330N	12630E	0038
47184		CHEJU	I M	3331N	12632E	0022
47187	RKPM	MOSULPO AB	T R P	3312N	12616E	0013
47189		SEOGIPO	I M	3314N	12634E	0052
47191		IRI		3555N	12657E	0008
47192		JINJU	I M	3511N	12805E	0025
47199	RKJO	YONG JUNG-RI	T	3626N	12626E	0037

*DATA TYPES

I = 3 hourly synoptic
M = 6 hourly synoptic
T = Metar
R = RAOB
P = Pibal
A = Forecast - TAF
D = Radar
(SFC ELEV in meters above MSL)

Table 6-2. Military observation stations and services provided.

CALL SIGN	STATION	USAF	ROKAF	24 HR FCST/ OBS	24 HR FCST	24 HR OBS	8-12 HR OBS	RAOB
RKJJ	KWANG-JU (K57)*		●	●				
RKJK	JUNSAN (K8)	●		●				
RKJO	YONGJUNG-RI		●				●	
RKNC	CHUNCHON	●		●			●	
RKNH	HOENGSAN		●					
RKNK	HYON-LI		●				●	
RKNN	KANGNUNG AB (K18)		●	●				
RKNS	SAMCHOK							
RKPE	CHINHAE		●				●	
RKPK	KIMHAE AB (K1)		●	●				
RKPM	CHEJU ISLAND (MOSUL PO AB) (K39)		●			●		●
RKPS	SACHON AB (K4)		●	●				
RKSB	UIJONBU	●					●	
RKSF	YONGDUNG PO, SEOUL (ROKAF WX CENTRAL)		●	●				
RKSG	PYONGTAEK	●			10 HR		●	
RKSM	SEOUL AB (K16) (10M SOF SEOUL)		●	●				
RKSN	KOON NI RANGE	●					●	PIBALS
RKSO	OSAN (K55)	●	●	●				●
RKSP	PAENGNYONG DO ISLAND (K53)		●				●	
RKSR	SINSANNI	●					●	
RKSS	KIMPO INTL. ARPT, SEOUL (K14)		●	●				
RKST	TONE DUCHON	●					●	
RKSU	YOJU		●				●	
RKSY	YONGJAN AI SEOUL	●			●		●	
RKSW	SUWON (K13)		●	●				
RKTD	TAEJON AB (K5)							
RKTG	CAMP WALKER, TAEJU SOUTH	●					●	
RKTH	POHANG (K3)		●				●	
RKTM	MANGIL SAN		●				●	
RKTN	TAEGU (K3)		●	●				
RKTS	SANGJU		●				●	

* K numbers are indicators for various air bases dating from the Korean Conflict and still in use today.

SECTION 7

CONTENTS

7. ENVIRONMENTAL SUMMARY FOR MAJOR FLEET OPERATIONS

7.1 INTRODUCTION

It is difficult to reach broad-based environmental conclusions for specific Fleet operations in Korean Peninsula waters because data for the same parameters often vary from source to source. The selection of truly representative data for a given parameter (e.g., swell, currents, temperature, etc.) is particularly difficult when considering space and time variations in the relatively small sea area around the Peninsula. This variability of data should be considered when the value of such general treatment is assessed.

7.2 OFFSHORE AND AMPHIBIOUS OPERATIONS

The sea approaches to South Korea are through the Sea of Japan, Korea Strait, East China Sea and Yellow Sea. The major hazards to navigation (other than the weather) occur near the coasts.

Offshore approaches to the east coast are generally deep and clear, whereas the west and south coasts have relatively shallow waters channelized by numerous islands, shoals, etc. Nearshore approaches to all coasts have at least some obstructions.

Sandbars are the most prevalent along the east coast, particularly to the north along the Kangwon coastline. On the west and south coasts, shoals, tidal flats, reefs and shifting sandbars offer numerous nearshore obstructions. Fish traps are obstructions all around the Peninsula.

Sea fog is a hindrance from late March through August, particularly June through August in the Yellow Sea and west coast areas. Gale force winds from the winter monsoon, typhoons tracking near the south coast and high surf are additional major restrictions to operations in South Korean waters. The very regular topography of the east coast offers a number of favorable areas for amphibious operations.

The nearshore gradients on most beaches are steep enough to permit dry-ramp LST landings. Tides are less than 1 ft (.3 m) north of Pohang, becoming 4 ft (1.2 m) in spring tides near Pusan. Beach widths on this coast generally vary from 30 to 900 ft (9-274 m). The major restriction on the east coast is the frequent high surf during the winter monsoon.

The south coast is deeply indented and is generally unsuited to amphibious operations. Beaches are mostly sand with an admixture of mud and gravel. Cultivated lowland strips and stream valleys border most beaches.

The deeply indented west coast, comprising shoals, mud flats, small islands and high tidal range, has relatively few beaches and generally is unsuited to amphibious operations.* Drying tidal flats fill numerous bays and estuaries and sometimes are found between the islands and the mainland. Surf on the west coast, as on the south, is generally less than critical (4 ft/1.2 m), but this advantage is largely outweighed by the disadvantages of topography and tide.

7.3 AIR OPERATIONS

Air approaches to South Korea are mainly over water via the Sea of Japan and Yellow Sea, the northern part of the East China Sea and the Korea Strait. An approach over the Japanese islands of Honshu and Kyushu provides major terrain obstacles with the highest peak 5866 ft (1788 m).

November through March is the best time of year for air operations over South Korea (and also ground operations) because cloudiness, thunderstorm activity and typhoon threats are at a minimum (see Para. 3.3). Any winter cloudiness is usually short-lived and associated with occasional migratory lows.

The summer months of June through August are the least favorable flying months because tropical storms and typhoons pose their biggest threats and overcast conditions frequently exist inland and over coasts. (Summer cloud cover over water is often broken when overcast conditions exist over land.) The rugged and high terrain restricts airborne, airmobile and parachute operations at all times. Within the region surrounding the Korean Peninsula, mountain peaks reach 12,000 ft (3658 m); in South Korea itself, heights reach 6000 ft (1829 m). Such terrain, coupled with low ceilings, makes air operations difficult; they are particularly hazardous for rotary wing aircraft. In addition, thunderstorm activity and turbulence is much more pronounced over the higher ground.

There are few suitable airfields within the mountainous terrain for high altitude attack aircraft. Year-round westerly headwinds make the eastern and southern approaches the least favorable sectors for approaching South Korea. Icing is of greatest concern for rotary wing aircraft. Light to occasionally moderate rime ice is a serious hazard that can still occur occasionally during the drier winter months. (See Paras. 3.3.11 and 4.5.9 for discussions of aircraft icing conditions and causes.)

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*U.N. forces made a large-scale landing at Inchon during the Korean Conflict, utilizing the large spring tidal range and operating each day at high tide.

7.4 ASW OPERATIONS

Data on the major physical properties of the seas around the Korean Peninsula are somewhat sparse; therefore, the emphasis here is on available information for the Sea of Japan. The intent is to note the physical variables that affect important ASW parameters and to reemphasize the inherent difficulties of ASW environmental prediction. (Available oceanographic data -- sea, swell, currents, bio-acoustic information, etc. -- are discussed in Para. 3.4 and in relevant portions of sections addressing seaward boundaries.)

The deep, cold, isothermal characteristics of the Sea of Japan make convergence zone propagation likely; ASW ranges of over 100 n mi (185 km) in this area are not uncommon. Deep-sound-channel propagation is possible, and variations in the depth and axial velocity of the deep-sound channel are relatively minor from season to season. Depths range from 492 ft (150 m) off South Korea to 1312 ft (400 m) off the coast of Japan.

The muddy bottom and depth of the Sea of Japan is not conducive to bottom bounce propagation, although here again applicable data are sparse. A recent study of sensor performance in the Sea of Japan showed that in the active mode, the winter season allowed the best detection results, given no-wind conditions. Even when the target is 200 ft (61 m) below the mixed layer depth, detection ranges greater than 50 n mi (93 km) can be expected. Convergence zones were found to exist only for the deep source/deep receiver combination in winter. In summer, convergence zones were found to be possible for all combinations of source and receiver (Kelly, Rawlinson and Peylor, NPS internal report).

7.5 GUNFIRE OPERATIONS

The primary gunnery ranges used by USAF and USN aircraft in South Korea are given below.

Name	Coordinates	Elevation ASL (ft/m)
Kooni Rng	3702N, 12644E	00/00
Nightmare Rng	3808N, 12720E	2000/610
Chik Do Rng	3553N, 12607E	00/00
Yong-jeong (R104)	3627N, 12626E	00/00
Nak Dŏng (R81)	3624N, 12813E	100/30

Weather minimums for range use vary according to the aircraft tactics employed and the type of ordnance loaded. Generally speaking, a ceiling/visibility of 3000 ft (914 m) or 3 n mi (5.5 km) will halt range operations. Weather for specific tactics are noted on the following page.

Ceilings (ft/m)	Visibilities (n mi/km)	Tactics
3000/914	3/5.5	Strafing and low angle drogue
4000/1219	4/7.4	Low angle dive toss
5000/1524	5/9.2	Close air support
6000/1828	3/5.5	Low angle low drogue
8500/2591	3/5.5	30° dive toss
10,500/3200	3/5.5	45° dive toss
14,500/4420	3/5.5	Hang angle dive toss

APPENDIX A
WEATHER TYPES IN THE EAST ASIAN / NORTHWEST PACIFIC AREA

The original type-classification of weather in the East Asian/northwestern Pacific area was accomplished in 1944 under CIT-AAF Project 1. Twelve weather types were identified, based primarily on the trajectory of low centers, wave developments or frontal zones. Extensive revisions in later years reduced these twelve types to seven, which are described here. The source of these descriptions is the publication Weather in the Far East, issued by the 20th Weather Squadron, 1st Weather Wing, in 1969.

A.1 TYPE 1

The two major features of type 1, which occurs in late fall, winter or early spring, are:

(1) A shallow quasi-stationary Asian anticyclone is centered over southern Siberia and Mongolia (Figure A-1). Its sea level surface pressure is less than 1050 mb. (This feature separates it from a type 4 situation.) A ridge or closed high may exist to 700 mb, but the anticyclonic circulation does not extend to 500 mb.

(2) A trough that has had no history on the surface chart in central Asia, moves eastward as a surface feature while regeneration occurs, possibly accompanied by frontogenesis. This usually occurs parallel to and near the Asian coast with the front or trough proceeding eastward and southeastward across the Korean Peninsula, Japan and the Northwest Pacific.

When the quasi-stationary, shallow high exists, all upper level troughs moving eastward in the westerly flow aloft should be extrapolated forward and surface regeneration suspected. While the trough remains aloft over the high, there is often little surface indication of its presence except for an area of poor weather confined to the more northerly latitudes. The first clues to its surface regeneration are the surface pressure tendencies along the eastern edge of the high. Occasionally, when the quasi-stationary high is elongated in an east-west direction, a small "bubble high" will break off from the main center with the trough forming behind it (Figure A-2).

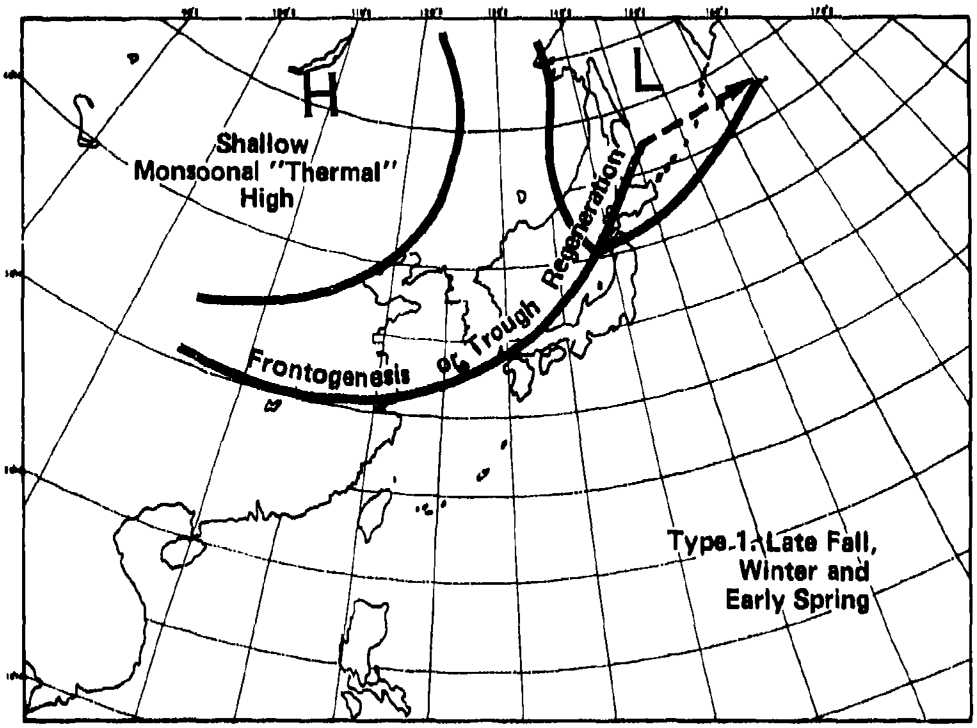


Figure A-1. Weather type 1 -- late fall, winter and early spring.

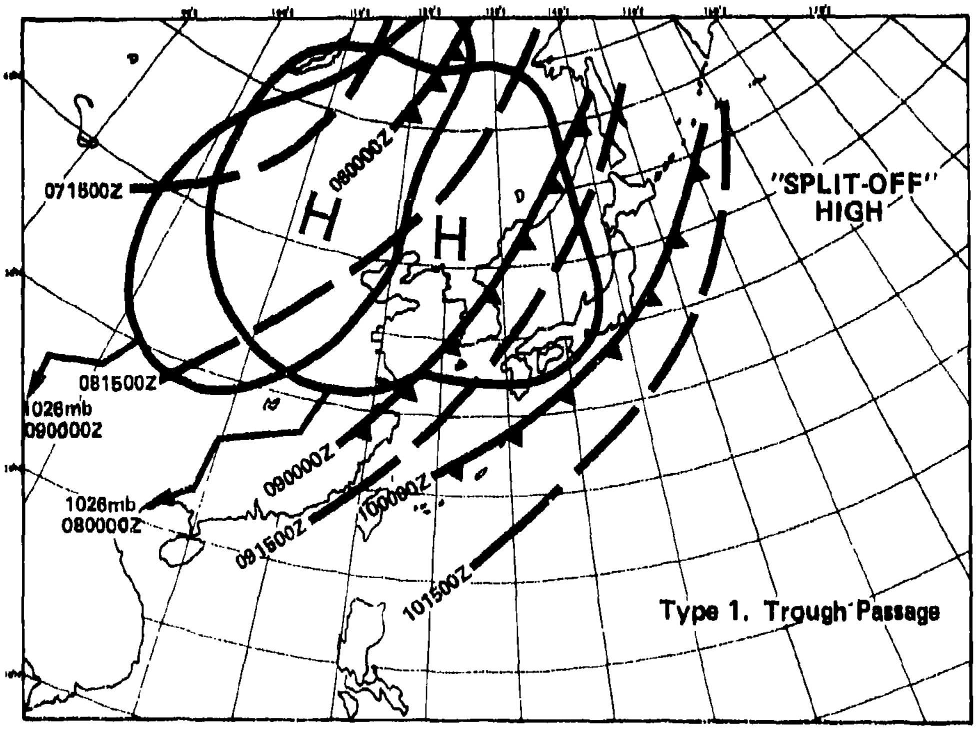


Figure A-2. Weather type 1 -- trough passage.

The weather associated with type 1 can be generally categorized as follows:

(1) Considerable cloudiness and showers over the windward areas of Japan, Sakhalin, the Ryukyus and adjacent waters.

(2) Generally fair conditions over the Korean Peninsula, central and eastern China and lee side areas of Japan.

(3) A large area of cloud and precipitation associated with the upper trough over the Asian mainland north of about 45°N.

(4) Low cloudiness and precipitation associated with the surface front over the Pacific and over southern and southeastern China as the front stagnates over this area.

A.2 TYPE 2

The major features of type 2 are: a low center or wave on the polar front (Figure A-3) develops over south or central China or the East China Sea and moves eastward and east-northeastward; and its trajectory is south of Japan or, more specifically, south of the Japan divide. Since weather type 2 may occur in any season, there are no characteristic features of the synoptic pattern over the Asian mainland associated with it.

Type 2 is most frequent during fall, winter and spring when the polar front lies south of Japan and across south and central China. There are several conditions favorable for wave formation on the front resulting in a type 2 low:

(1) In spring and fall, and occasionally in winter, a migratory high moves eastward across Japan following the polar front. As the front stagnates in its southern portion over South China, a type 2 low will form and move northeastward along the front behind the high (Figure A-4). Extensive pre-frontal high level cloudiness will usually develop rapidly as the ridge line passes.

(2) A second favorable condition for formation of a type 2 low is a quasi-stationary polar front lying between 15-25°N with a moderate westerly trough moving eastward across Asia. If the trough is strong enough, it will cause winds ahead of it to back into a southwesterly direction and trigger a type 2 low on the stationary front (Figure A-5a).

(3) A third favorable situation occurs during late fall, winter and early spring with a ridge of high pressure extending southeast over Japan and the northwest Pacific (Figure A-5b; note the different air trajectories around the main high cell and the extended ridge). This type 2 low does not necessarily form on the polar front and it does not normally repeat itself since the over-extended ridge is usually broken by the first low.

(4) The fourth situation occurs in late spring, summer and early fall when the polar front lies just south of Japan and separates the polar maritime and tropical maritime air. A series of small, stable waves move along the front and normally do not occlude until they are east of Japan.

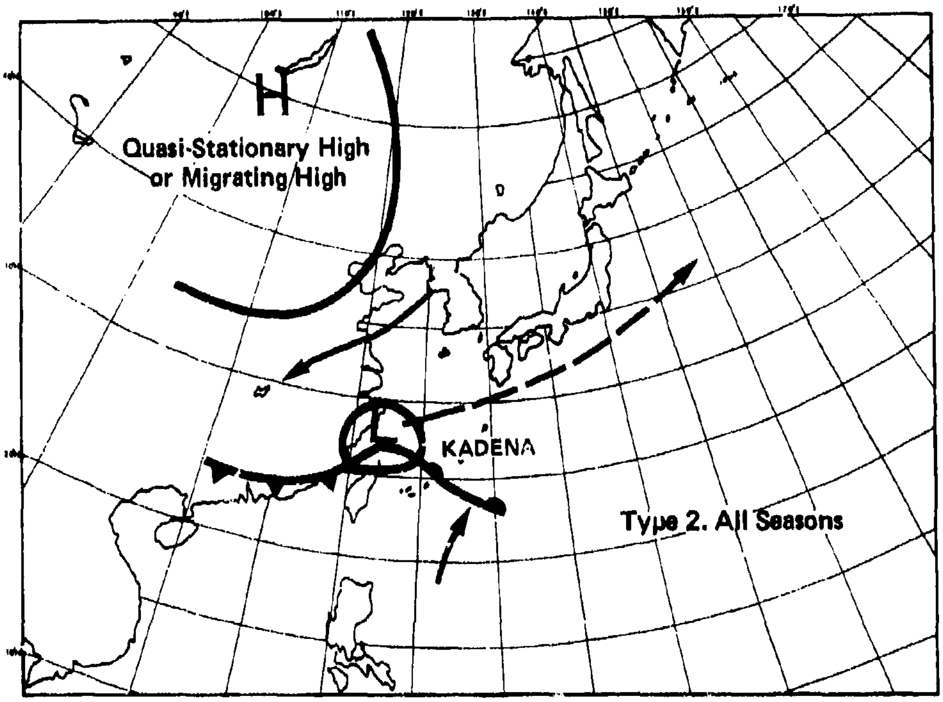


Figure A-3. Weather type 2 -- all seasons.

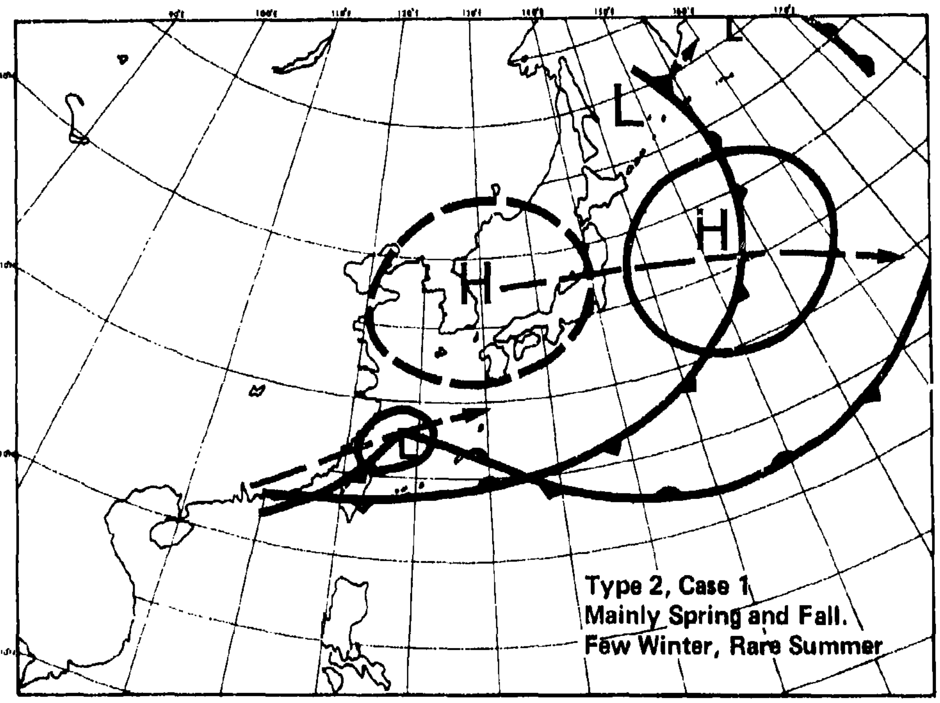


Figure A-4. Weather type 2, case 1.

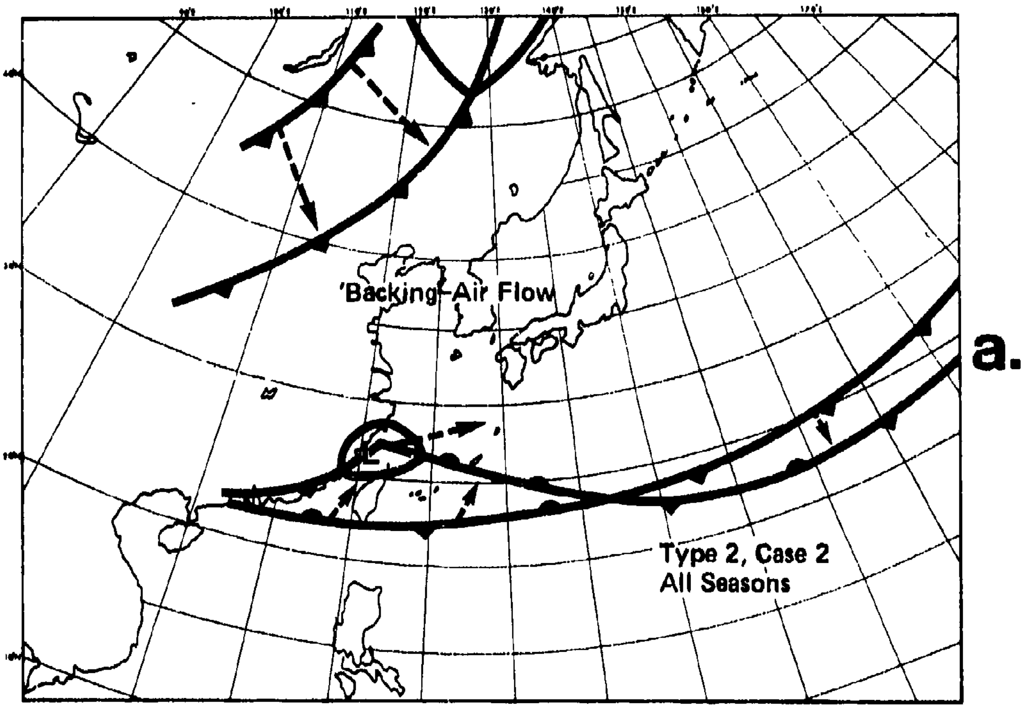


Figure A-5a. Weather type 2, case 2.

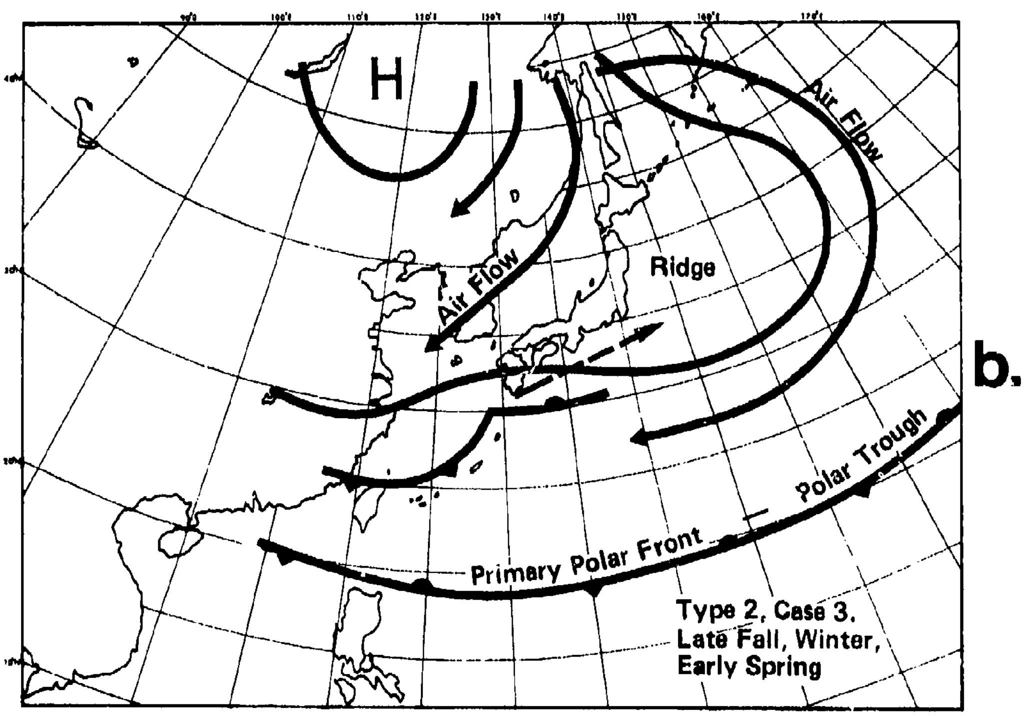


Figure A-5b. Weather type 2, case 3.

The poor weather associated with type 2 lows -- low cloudiness and precipitation -- is usually confined to areas south of the Japan divide, and the adjacent ocean area. However, they represent a complex problem to the forecaster because of the rapid spread of poor weather northeastward in advance of a low. Forecasters must constantly watch for early signs of wave formation over South China and adjacent sea areas.

The lack of data in this area is a large part of the problem. Stable waves do not appear to have any simple type periodicity, and wavelengths may vary from 200 to 800 n mi (370-1482 km). They appear to move with a mean speed of about 29 kt and should be extrapolated with the speed of the 850 mb winds over the wave center. These waves also tend to dissipate and reform in a new location so that the latest analyzed position based on data should outweigh any continuity consideration in analysis. An isotach maximum in the 850-700 mb layer has been observed to accompany the wave crest in some cases. Winds in this level have been reported to increase from 20 to 80 kt in a 12-hour period during a crest passage.

A.3 TYPE 3

The principal feature of a type 3 weather situation is a low cell or wave which forms on the polar front or in the polar trough over central or northern China, the northern part of the East China Sea or over the Yellow Sea, and moves northeastward across the Korean Peninsula and northern Japan. A type 3 low maintains its position north of the Japanese mountain divide until it reaches northern Japan. In unusual cases, the low may first appear as far east as the Peninsula and the Sea of Japan.

Type 3 lows appear in all seasons of the year and their formation processes are similar to those of a type 2 low, except that the cyclogenetic area is displaced further north (Figure A-6). The synoptic conditions favorable for formation are similar to those described in Para. A-2, items (1), (2), (3) and (4).

A special case of both type 2 and type 3 lows is the so-called double-eye type; examples are shown in Figures A-7 and A-8. In Figure A-7, a type 3 low has moved northeastward toward Japan and occluded with the base of the occlusion south of Japan. With cyclogenesis at the base of the occlusion, a double eye forms. The new low moves northeastward as a type 2 low and becomes the main center while the original type 3 low dissipates in the Sea of Japan. In Figure A-8, the double eye begins as a type 2 low and moves northeastward south of Japan. When its path is close to the eastern coast of Japan, a dynamically induced low forms on the other side of the mountain barrier over the Sea of Japan. The original type 2 low maintains itself as the primary center while the type 3 induced low in the Sea of Japan fills.

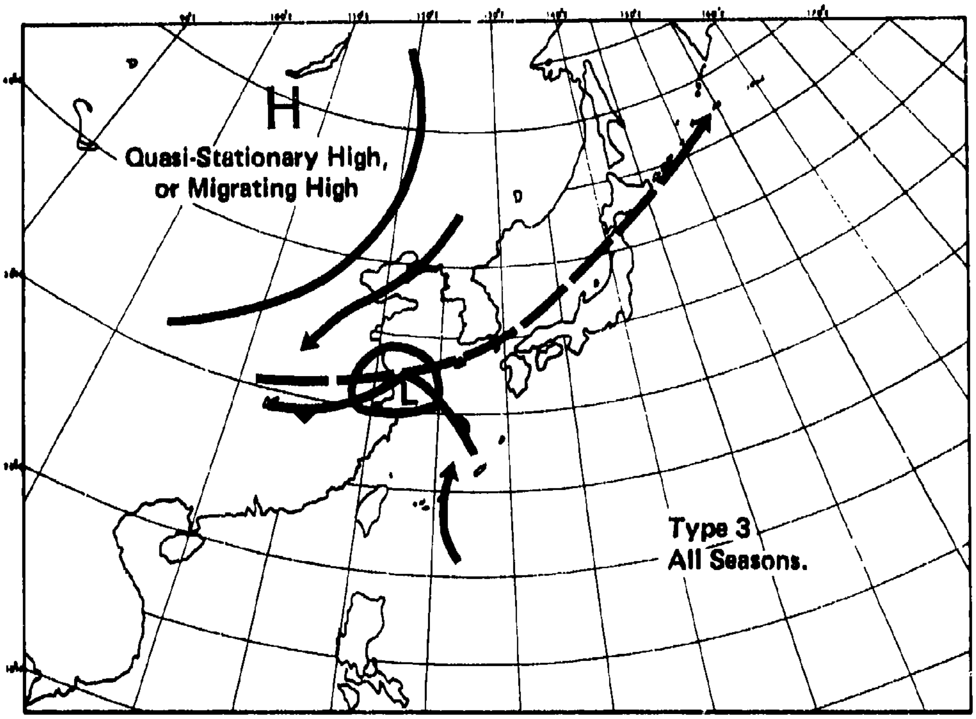


Figure A-6. Weather type 3 -- all seasons.

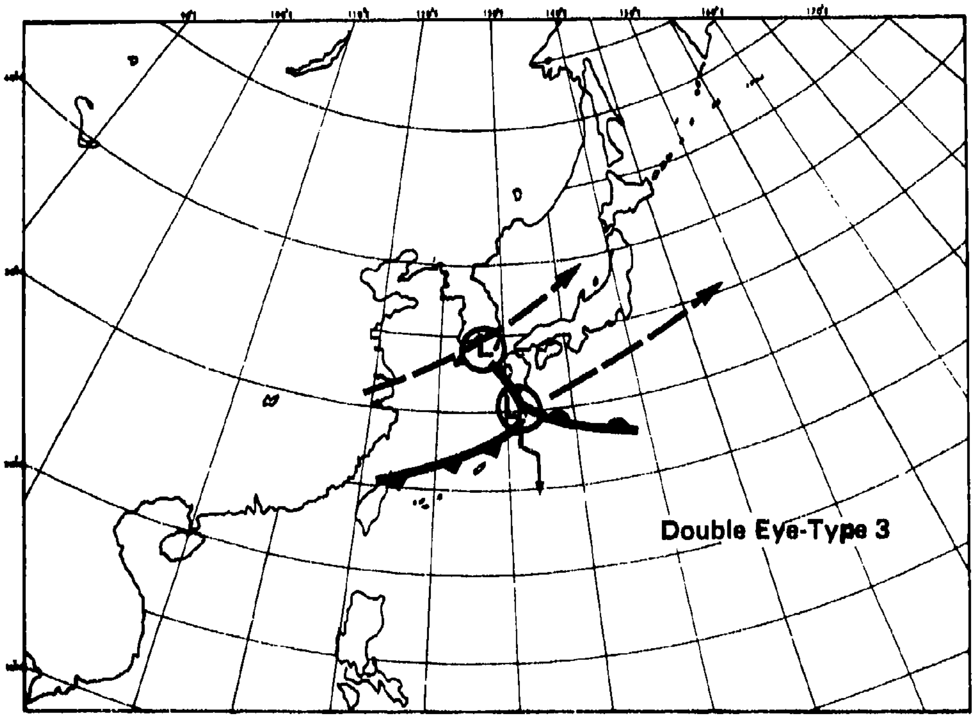


Figure A-7. Double eye, weather type 3.

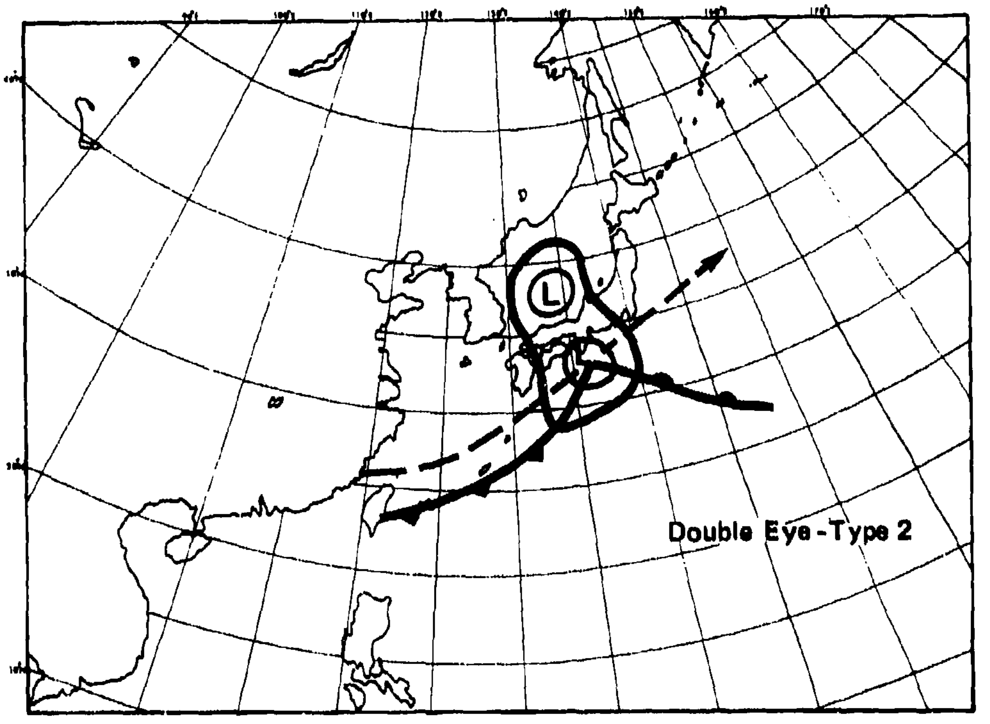


Figure A-8. Double eye, weather type 2.

The poor weather associated with a type 3 low is normally confined to the northern side of the Japanese divide, the Yellow Sea, the Korean Peninsula, Sea of Japan and the adjacent Asian coastal areas. However, the double eye situation produces the most widespread area of unfavorable weather of any of the types. Since the weather over the area of interest is quite different with a type 2 or 3 low, it is important that the forecaster distinguish between the two types at an early stage of development. This is extremely difficult since the conditions favorable for development are quite similar. An empirical rule states, for a low generated over China, that if it passes 120°E longitude south of 30°N it will be a type 2, and if it passes north of 30°N it will be a type 3. However, the latitude of the main polar front or trough, the position of the Asian high, and the upper level steering pattern must also be given full consideration.

A-4 TYPE 4

The main features of a type 4 situation are a "warm" core Siberian high and a minimum of frontal activity over East Asia and the northwest Pacific.

The warm high is quasi-stationary with a sea level pressure intensity of greater than 1050 mb and with a closed anticyclonic circulation extending to at least 500 mb. Type 4, therefore, is a blocking high situation so that westerly troughs and fronts are steered far to the north and have no effect over Japan and the areas of interest (Figure A-9).

Type 4 patterns occur primarily in winter and in late fall and early spring. The polar front has moved far south along a line from the Philippines to the Marianas and the entire East Asian-northwest Pacific area is dominated by the high. As with most blocking cases, type 4 is a rather persistent feature which, when identified, can provide the basis for a reliable forecast for several days.

The weather associated with type 4 is generally good. However, individual locations must always be considered on the basis of trajectory of the air mass, terrain, sea temperatures, etc. The windward side of Honshu, in particular, will have extensive and heavy cumulus and much snowshower activity. There is likely to be much above-average cumulus activity and turbulence over the seas south and east of Japan.

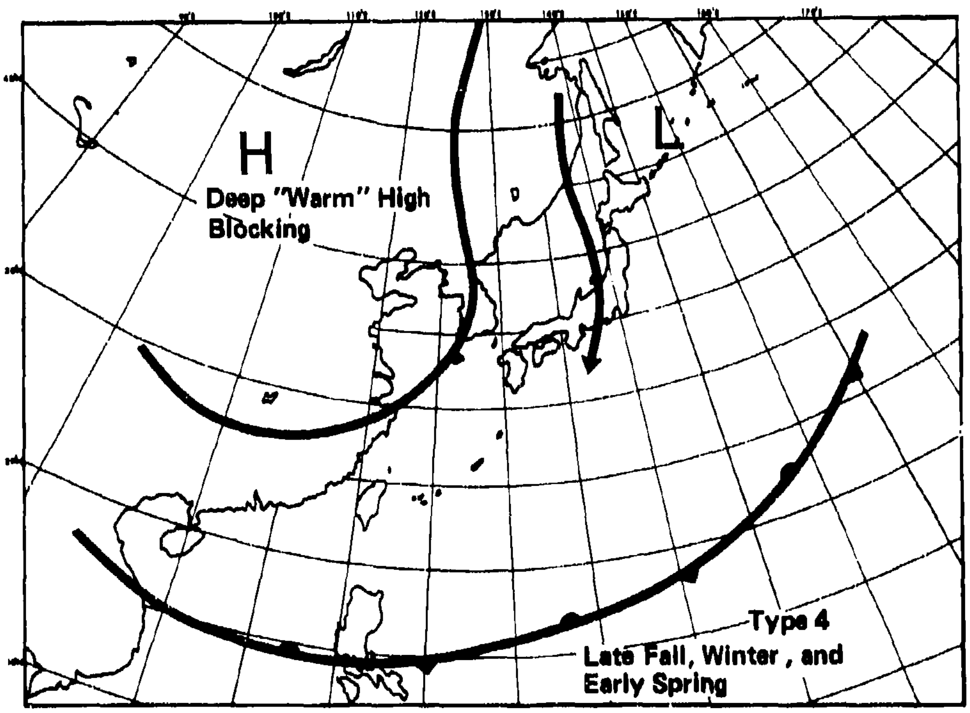


Figure A-9. Weather type 4.

A.5 TYPE 5

The principal feature of type 5 is a frontal system or trough to the west moving eastward across the East Asian-northwest Pacific area (Figure A-10). It differs from type 1 in that the trough or front can be identified at the surface as it moves eastward and usually acts as the divider between successive migrating highs.

Type 5 occurs with a high frequency during all seasons and is often associated with one of the other types. It frequently acts as the trigger mechanism to induce wave cyclogenesis over China for type 2 and type 3 lows. Occasionally, variations of the type 5 occur in which a secondary low forms along the front or in the trough south of the primary type 5 low center. These secondary low centers may move on an easterly track or divert south over the Korean Peninsula or Japan in unusual cases (Figure A-10).

The weather associated with type 5 depends on the season, the air mass contrasts and the circulation intensity. Since a type 5 system moves west to east, the major effects are found on the windward exposures. The typical or "model" weather associated with cold fronts and troughs at similar latitudes over other areas of the world is found here also. This weather cannot be generalized.

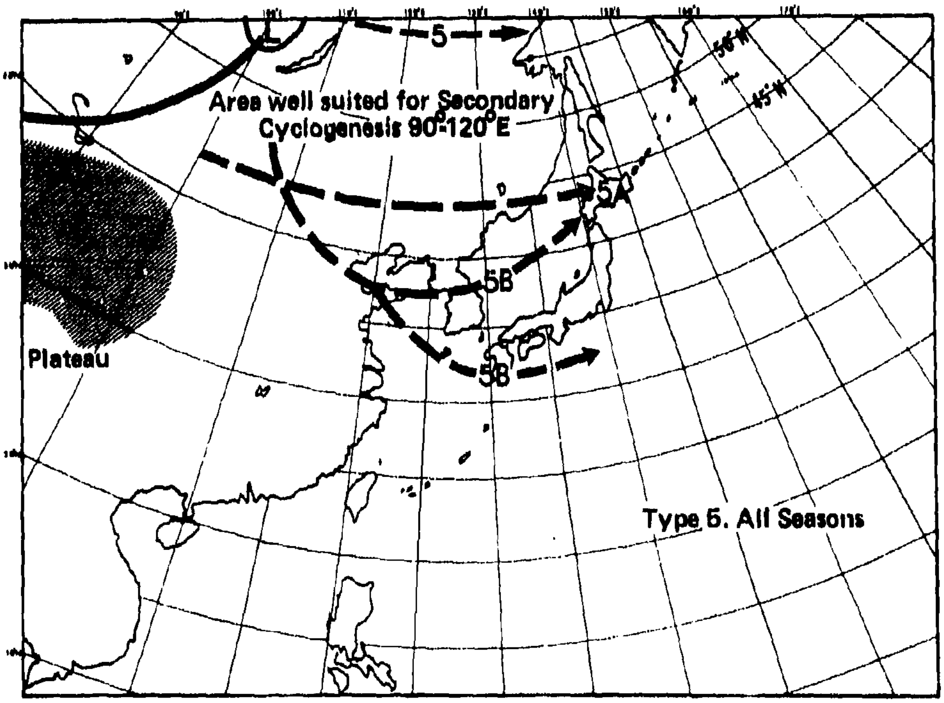


Figure A-10. Weather type 5.

A.6 TYPE 6

The distinguishing features of a type 6 situation are:

(1) The northward flow of tropical maritime air around the western lobe of the Pacific high.

(2) A high cell in the Sea of Okhotsk area that has a low level flow of polar maritime air westward along its southern boundary.

(3) The polar front or trough oriented approximately east-west forming the boundary between the polar maritime and tropical maritime air (Figure A-11).

Type 6 is a late spring, summer and early fall occurrence. The Okhotsk high is either a migrating high from China or Mongolia, or a southward extension of a high over eastern Siberia or the Bering Sea, or a new feature produced by anticyclogenesis over the cold sea of Okhotsk in late spring. It may or may not be persistent. The polar front or trough will normally be located south of Japan through early July and north of Japan during late July and August.

Large areas of low cloudiness and rain occur with weather type 6 north of the polar front. This type is prevalent during the "Bai-U" or "plum rains" in late June and July. With a shallow polar maritime air mass, the overrunning tropical maritime air mass causes the unfavorable weather to extend far to the north. South of the frontal boundary, tropical maritime air mass weather predominates.

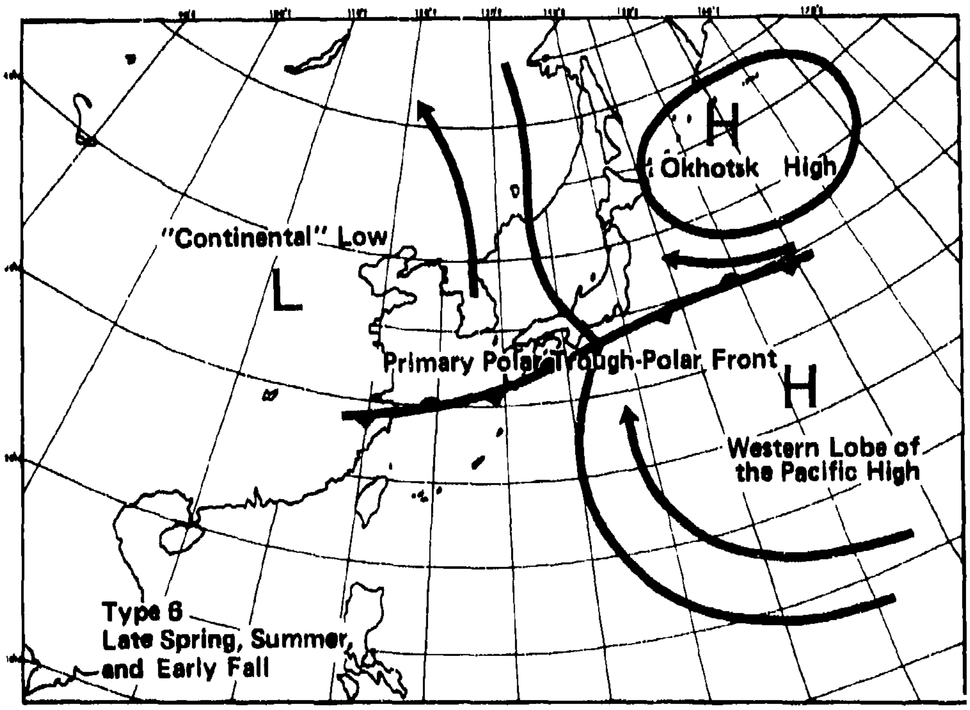


Figure A-11. Weather type 6.

A.7 TYPE 7

The main feature of this type is a migrating high that moves from the interior of Asia across the mid-latitude coastal area and into the Pacific (Figure A-12).

Type 7 occurs primarily in spring and fall, infrequently in winter, and rarely in summer. The type is associated with a high index situation and the high can be extrapolated quite well. The type 7 high is usually followed by a type 5 trough and strong consideration must be given to the possibility of wave formation to the southwest of the high cell.

Some unfavorable weather occurs with type 7 in the return circulation on the southwest side of the high. Otherwise, the weather is generally good throughout the area traversed by the type 7 high.

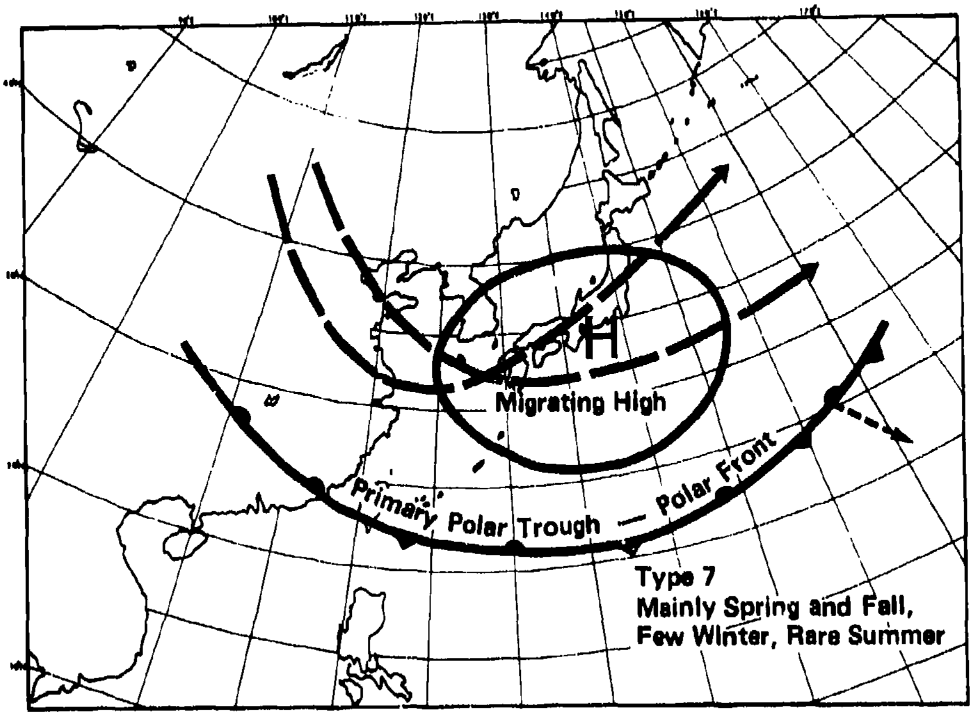


Figure A-12. Weather type 7.

APPENDIX B
SUNRISE / SUNSET DATA

The 24 nomograms contained in this appendix, drawn at semimonthly intervals, facilitate rapid determination of approximate times (ZULU) of sunrise and sunset for any given location in the Korean area.

(1) Solid lines indicate times of sunrise.

(2) Dashed lines indicate times of sunset.

(3) Twilight, 45°N to 35°N, is approximately 30 minutes before sunset.

(4) Twilight, 35°N to 10°N, is approximately 25 minutes before sunset.

(5) Local time in the Korean area = ZULU time + 9 hours.

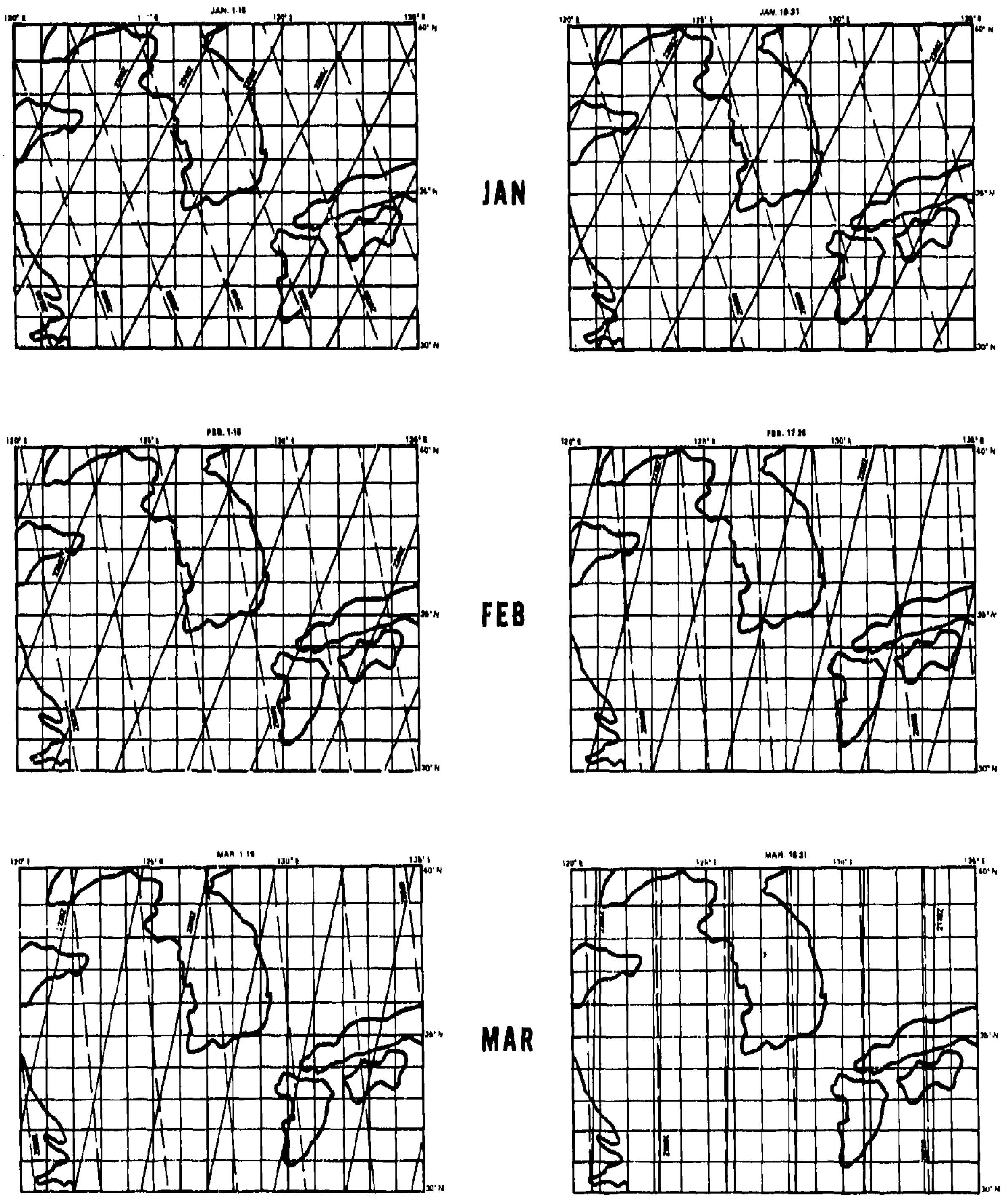


Figure B-1. Sunrise/sunset nomograms, January-March.

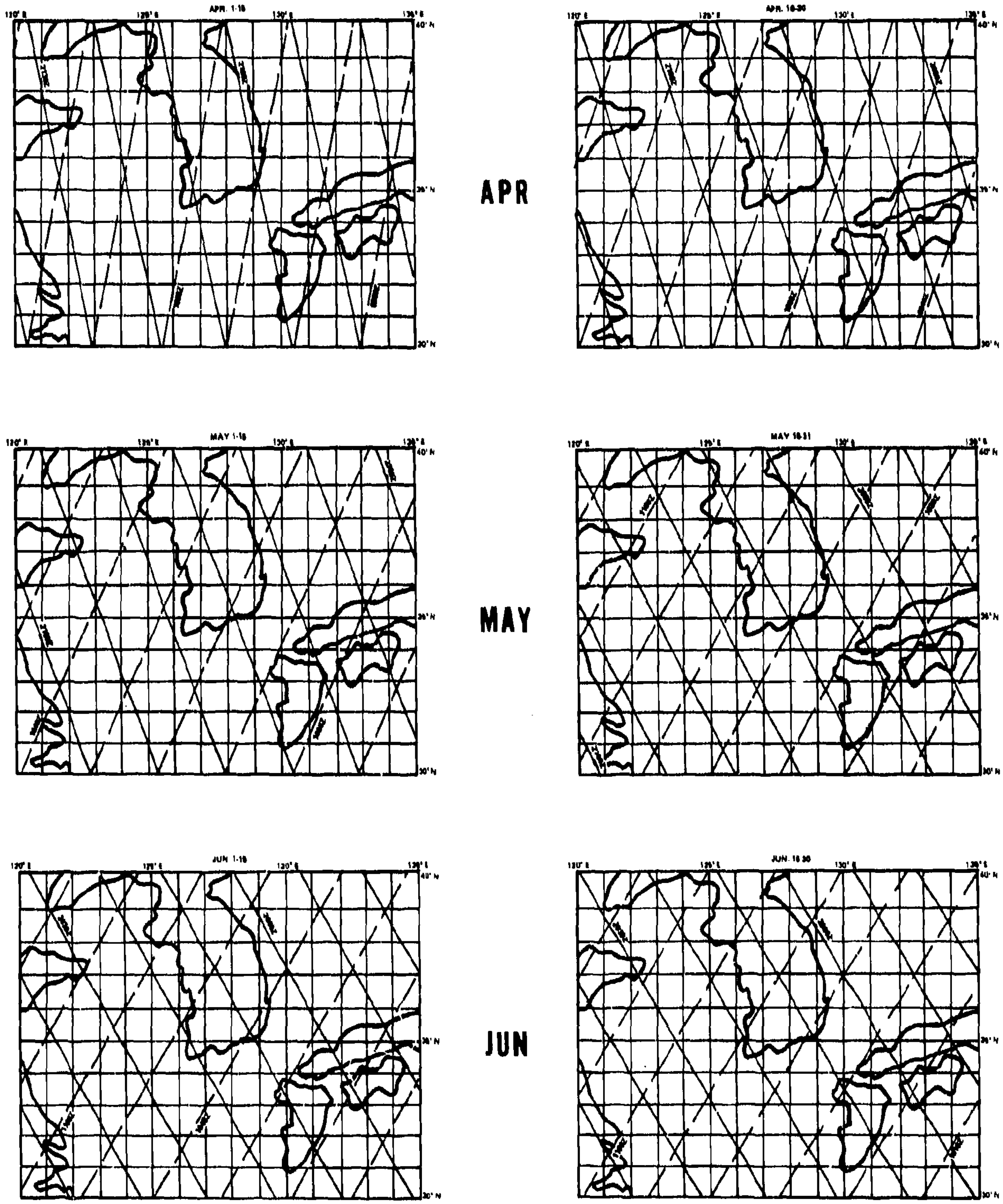


Figure B-2. Sunrise/sunset nomograms, April-June.

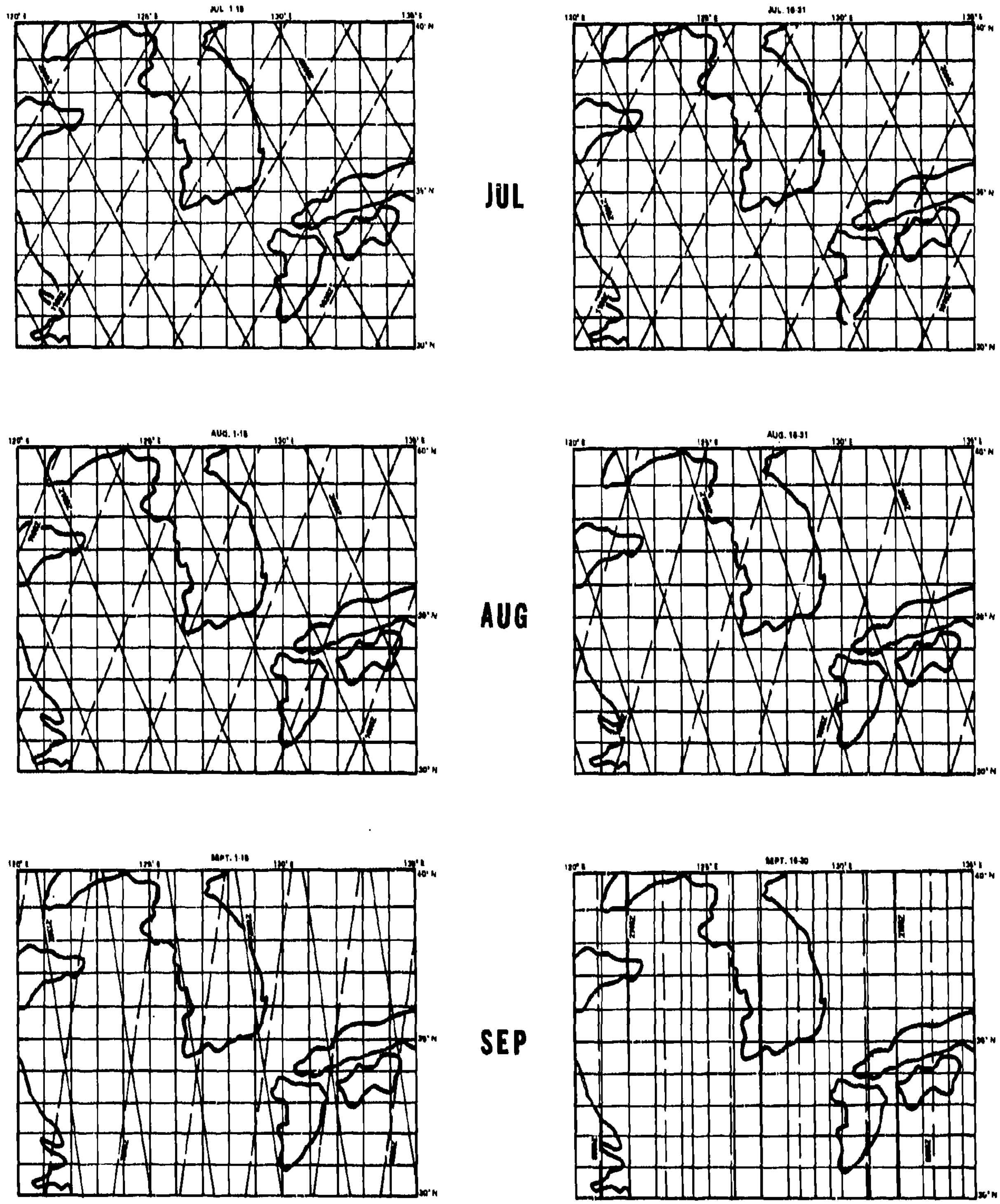


Figure B-3. Sunrise/sunset nomograms, July-September.

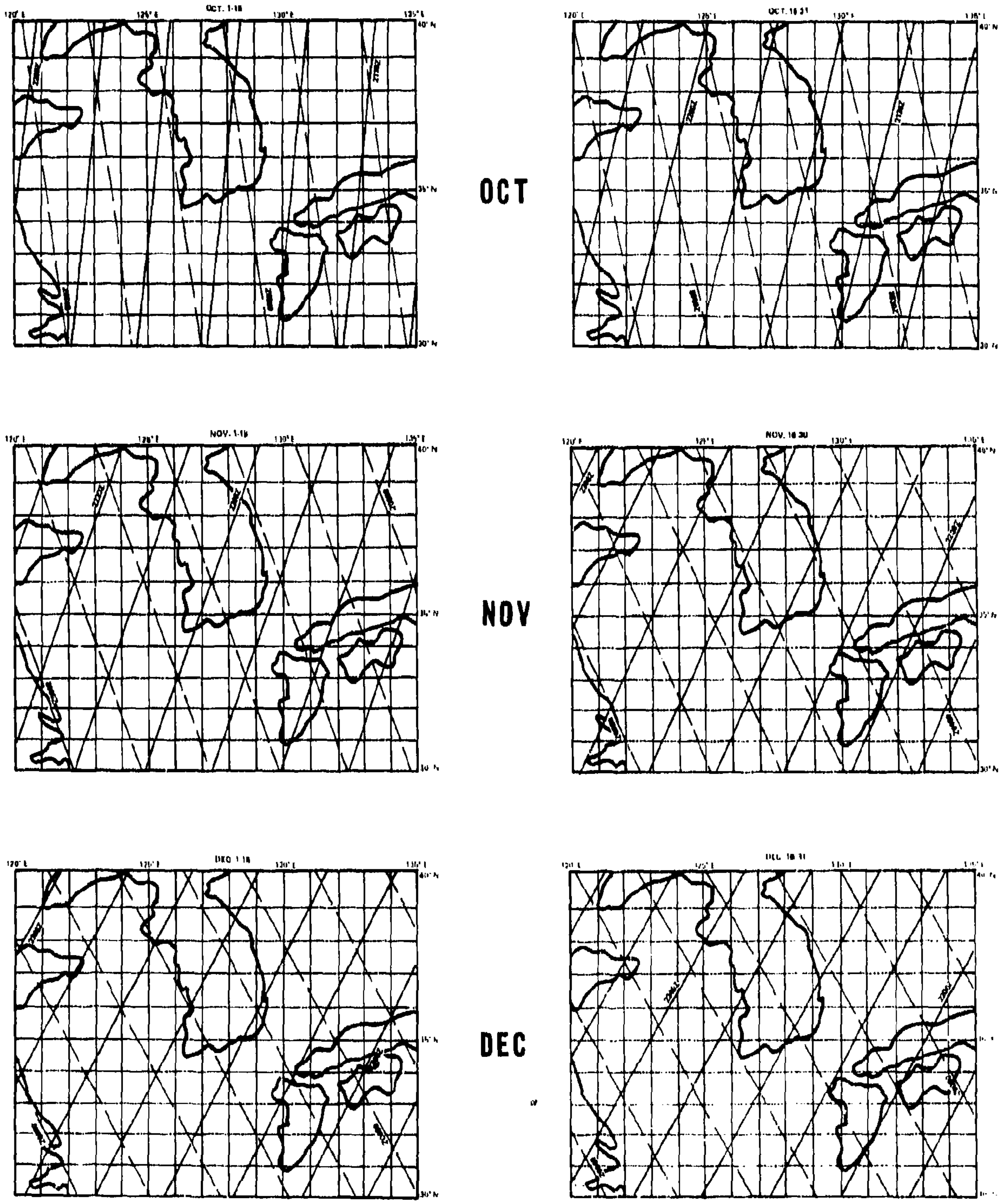


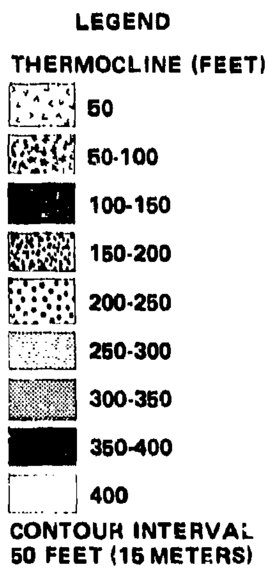
Figure B-4. Sunrise/sunset nomograms, October-December.

APPENDIX C
THERMOCLINE DATA

Figures C-1 through C-12 (Jan-Dec) depict mean monthly depths to the top of the thermocline for the Korean region. The legend for interpreting the graphic presentations is shown below; dashed lines represent the 400 ft bottom contour.

Figure C-13 is a locator map showing seven data locations A through G around the Korean Peninsula.

Figures C-14 through C-25 depict (1) monthly sound speed vs. depth profiles and (2) monthly temperature vs. depth profiles for the seven locations A through G shown in Figure C-13.



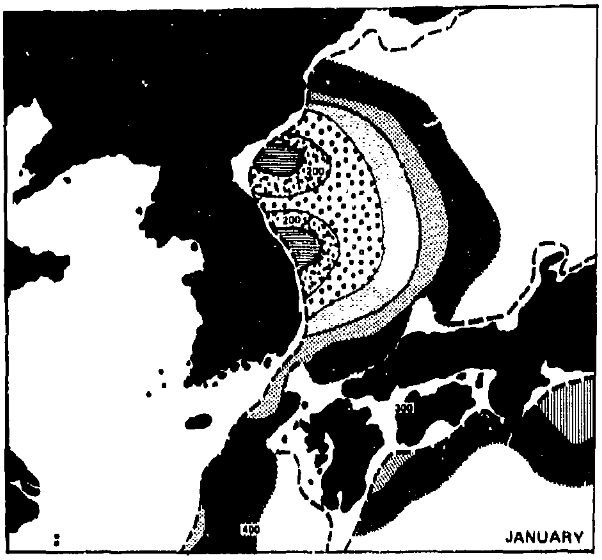


Figure C-1. Thermocline data for January.

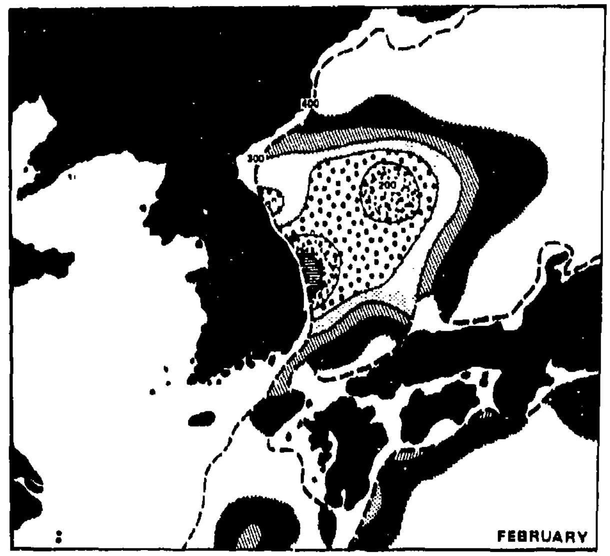


Figure C-2. Thermocline data for February.

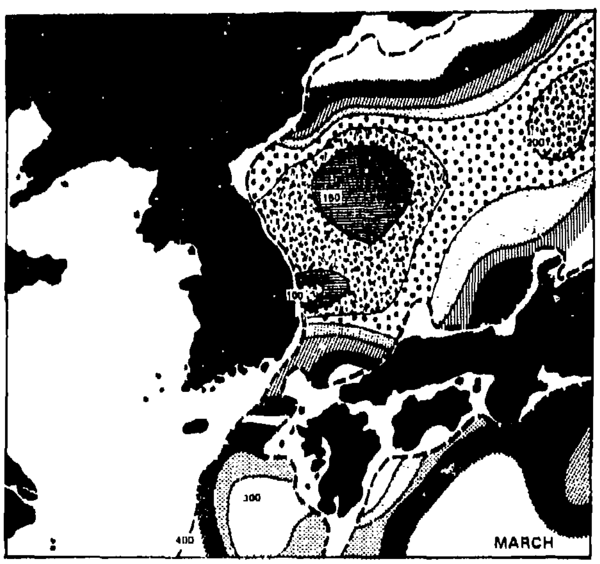


Figure C-3. Thermocline data for March.

Figure C-4. Thermocline data for April.

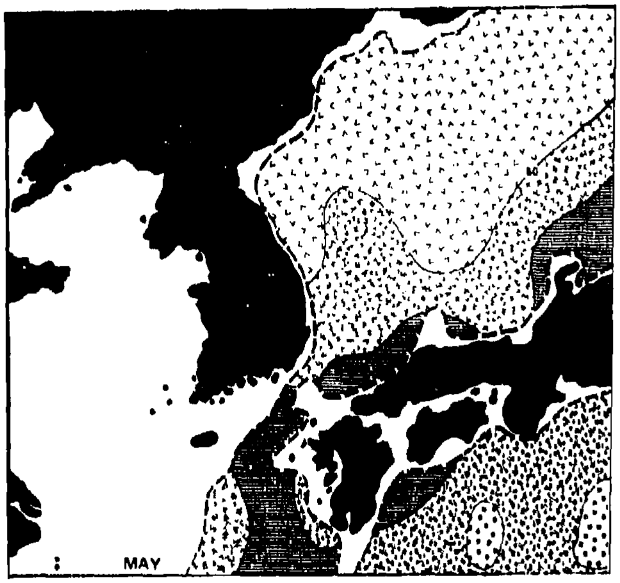


Figure C-5. Thermocline data for May.

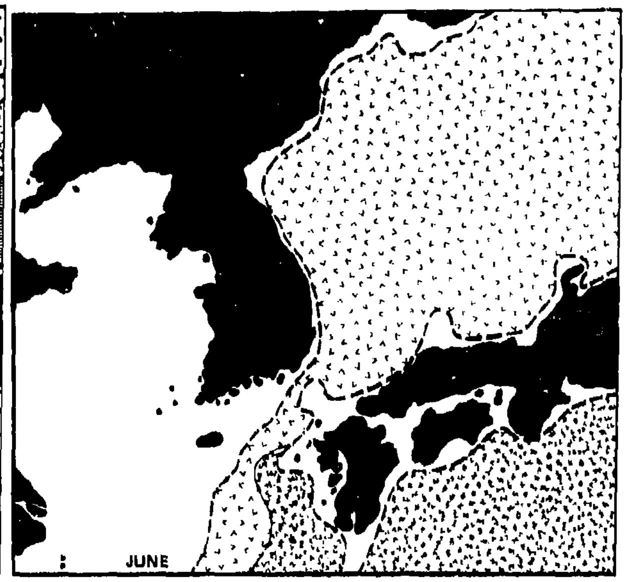


Figure C-6. Thermocline data for June.

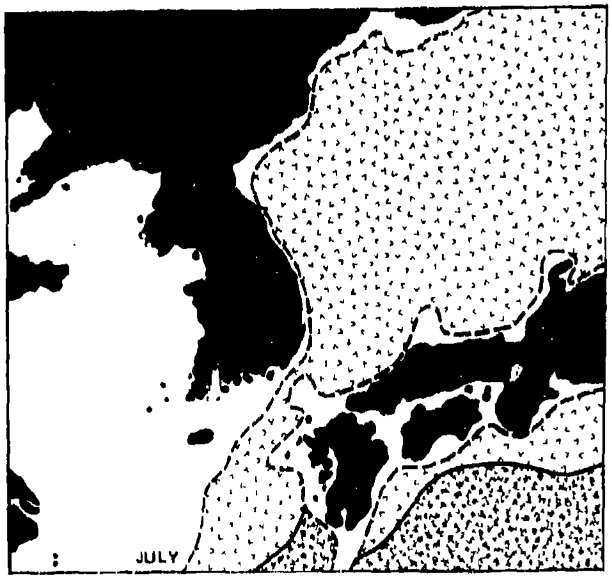


Figure C-7. Thermocline data for July.

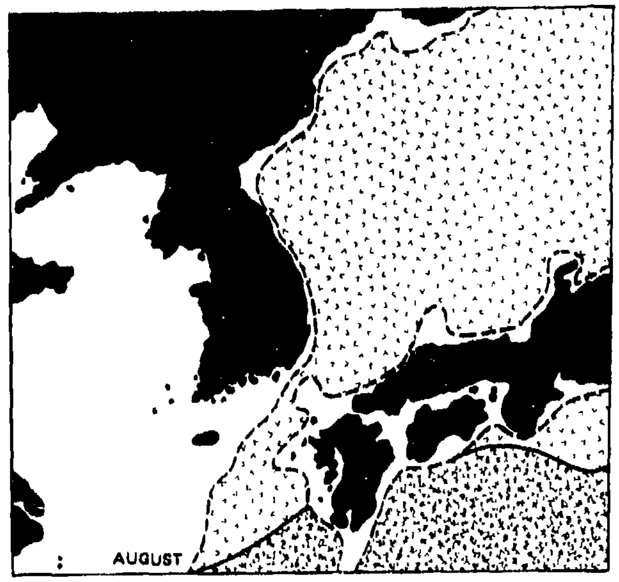


Figure C-8. Thermocline data for August.

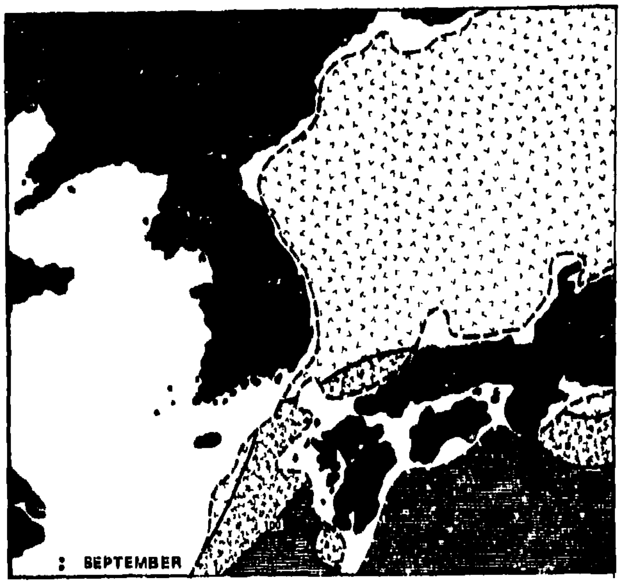


Figure C-9. Thermocline data for September.

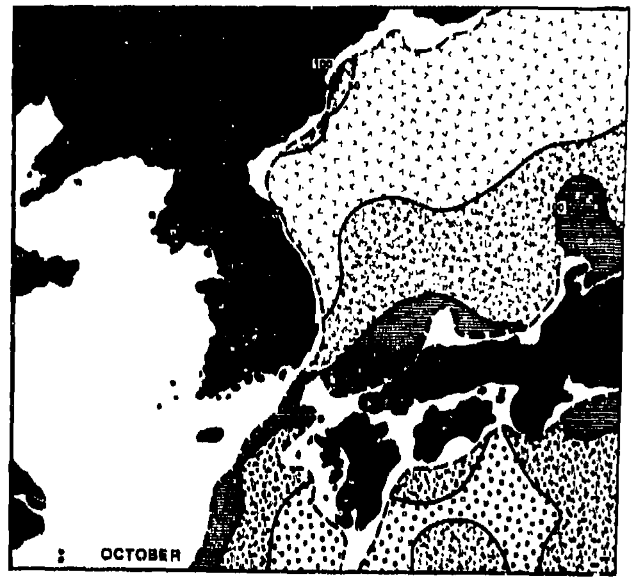


Figure C-10. Thermocline data for October.

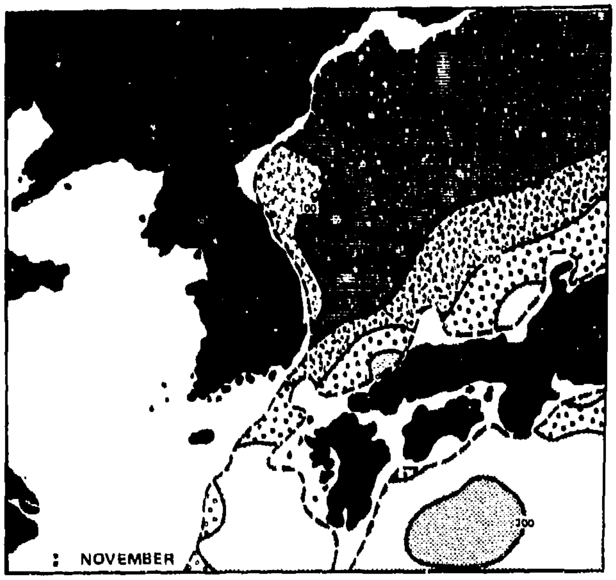


Figure C-11. Thermocline data for November.

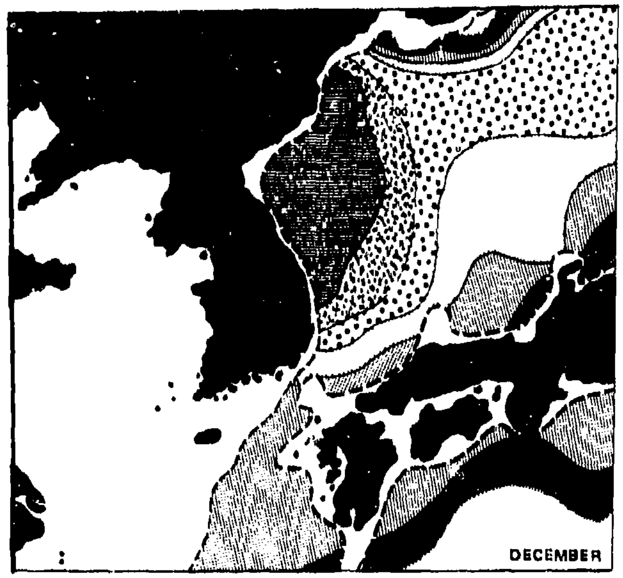
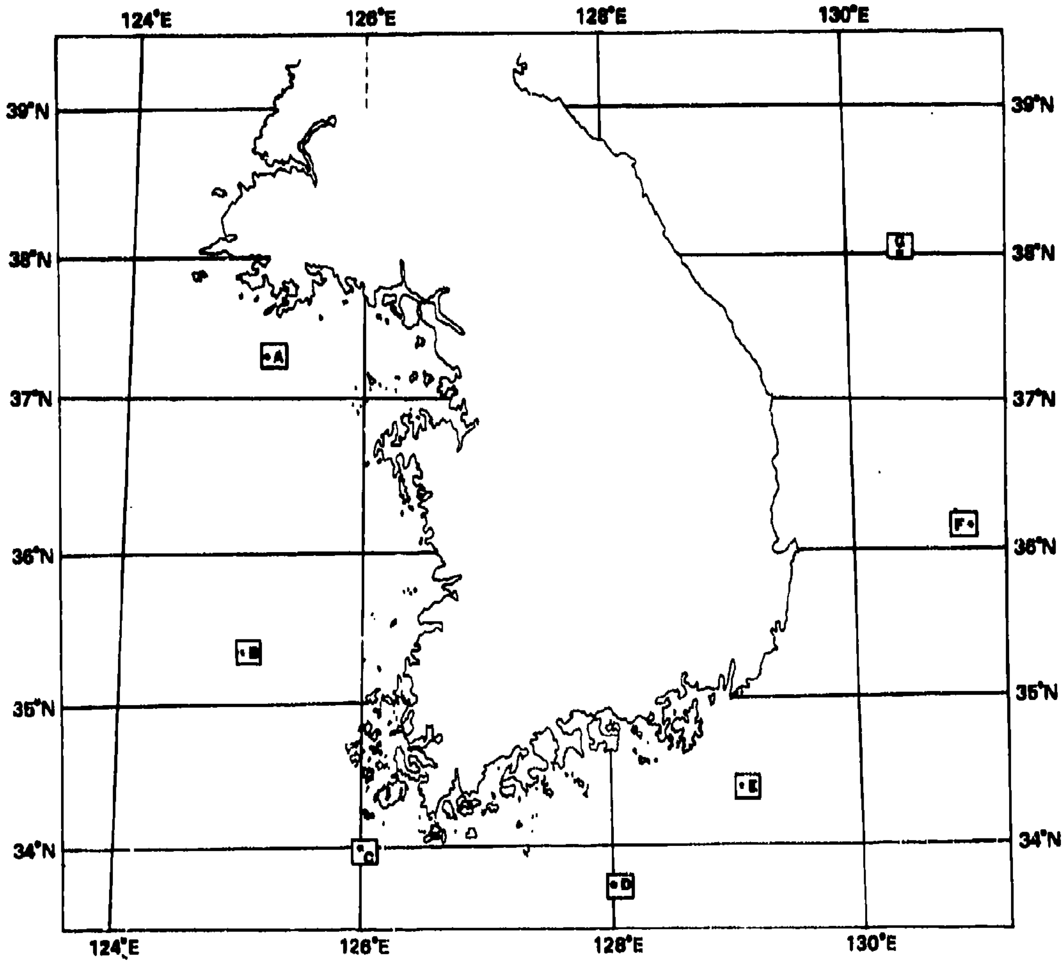


Figure C-12. Thermocline data for December.



LEGEND

LOCATION INDEX

AREA	LAT. / LONG.
A	37.3°N/125.2°E
B	35.3°N/125.0°E
C	34.0°N/126.0°E
D	33.7°N/128.0°E
E	34.7°N/129.0°E
F	36.2°N/131.0°E
G	38.0°N/130.5°E

Figure C-13. Locator map: data locations A through G.

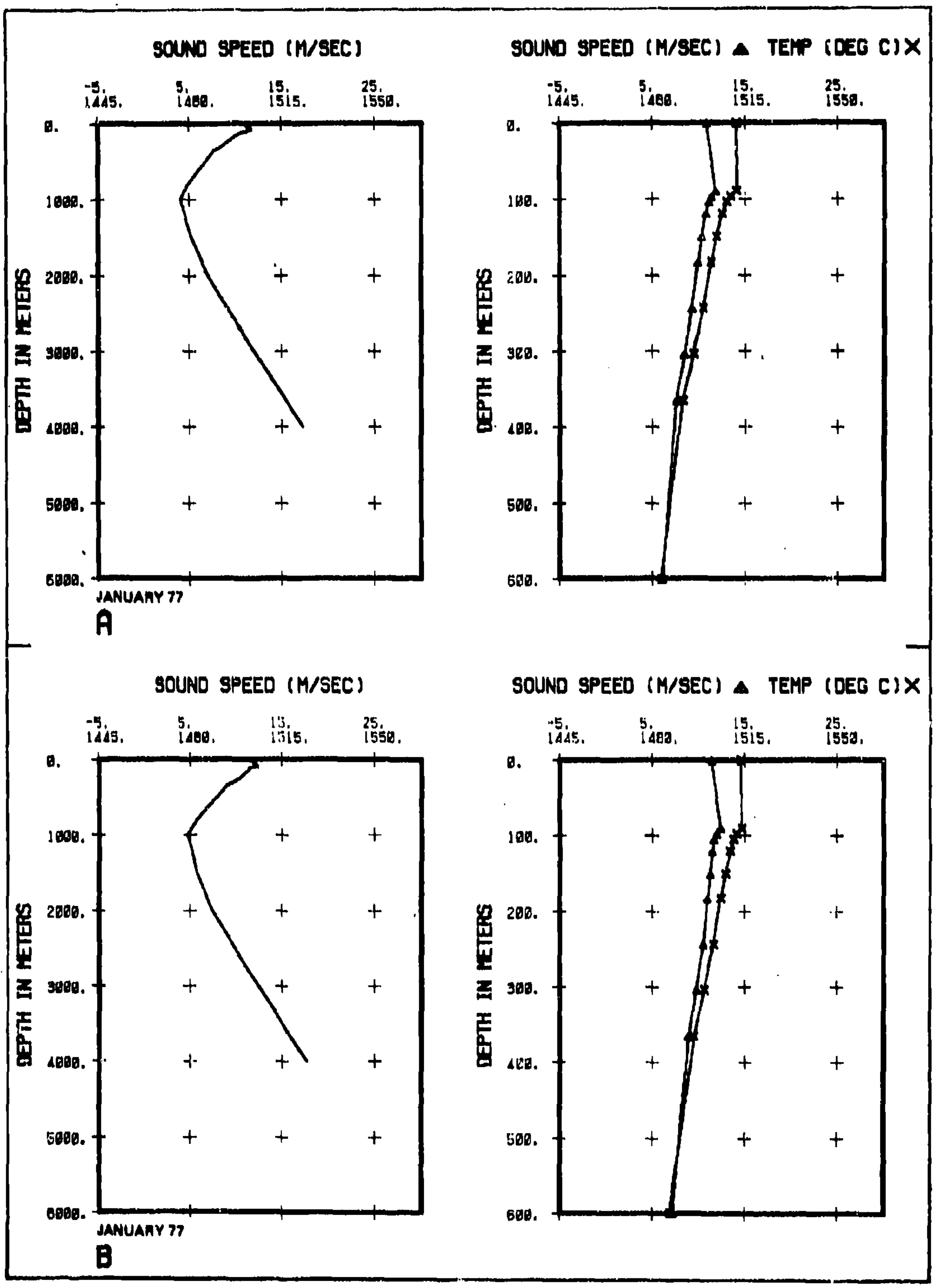


Figure C-14. Profiles for January.

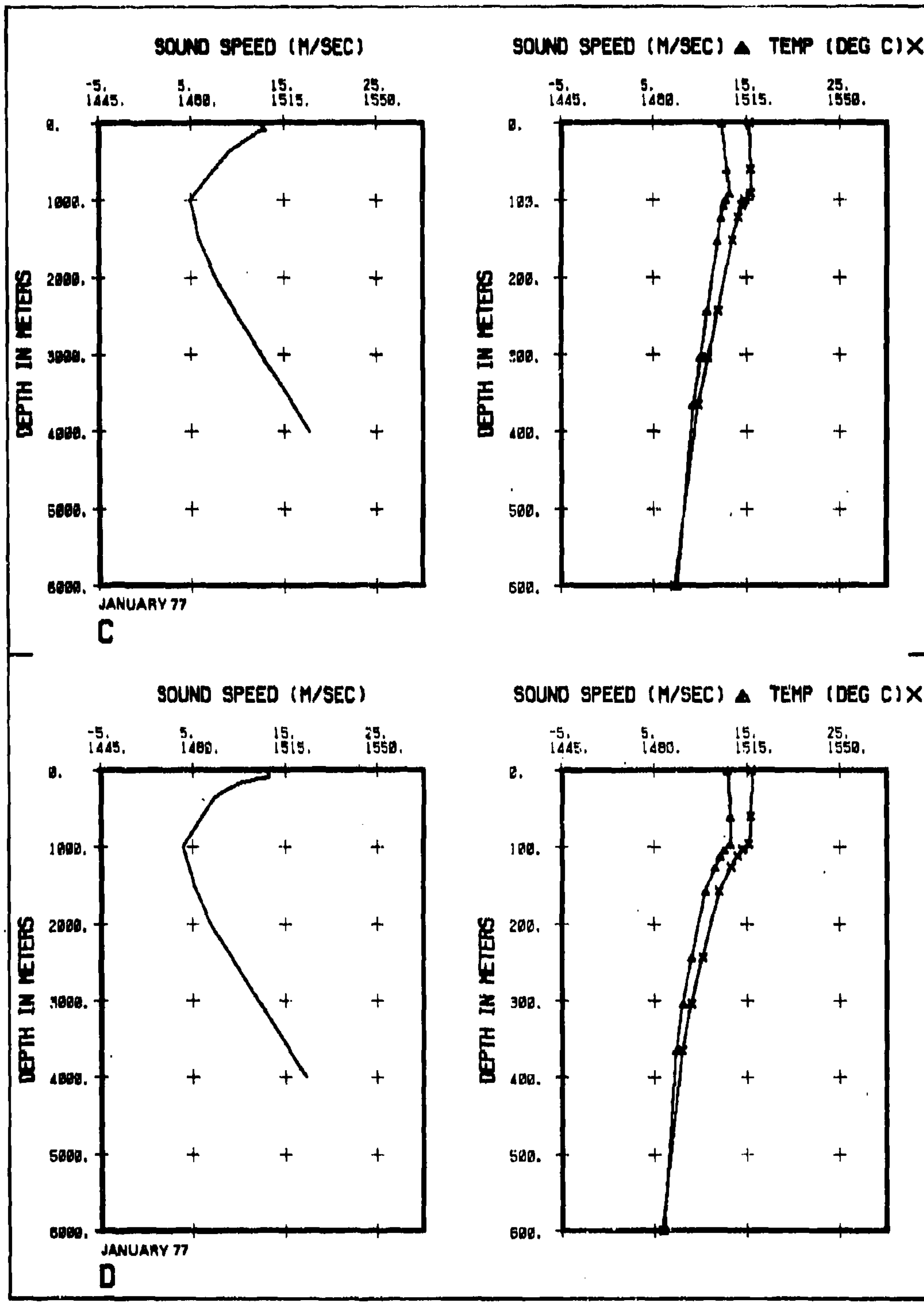
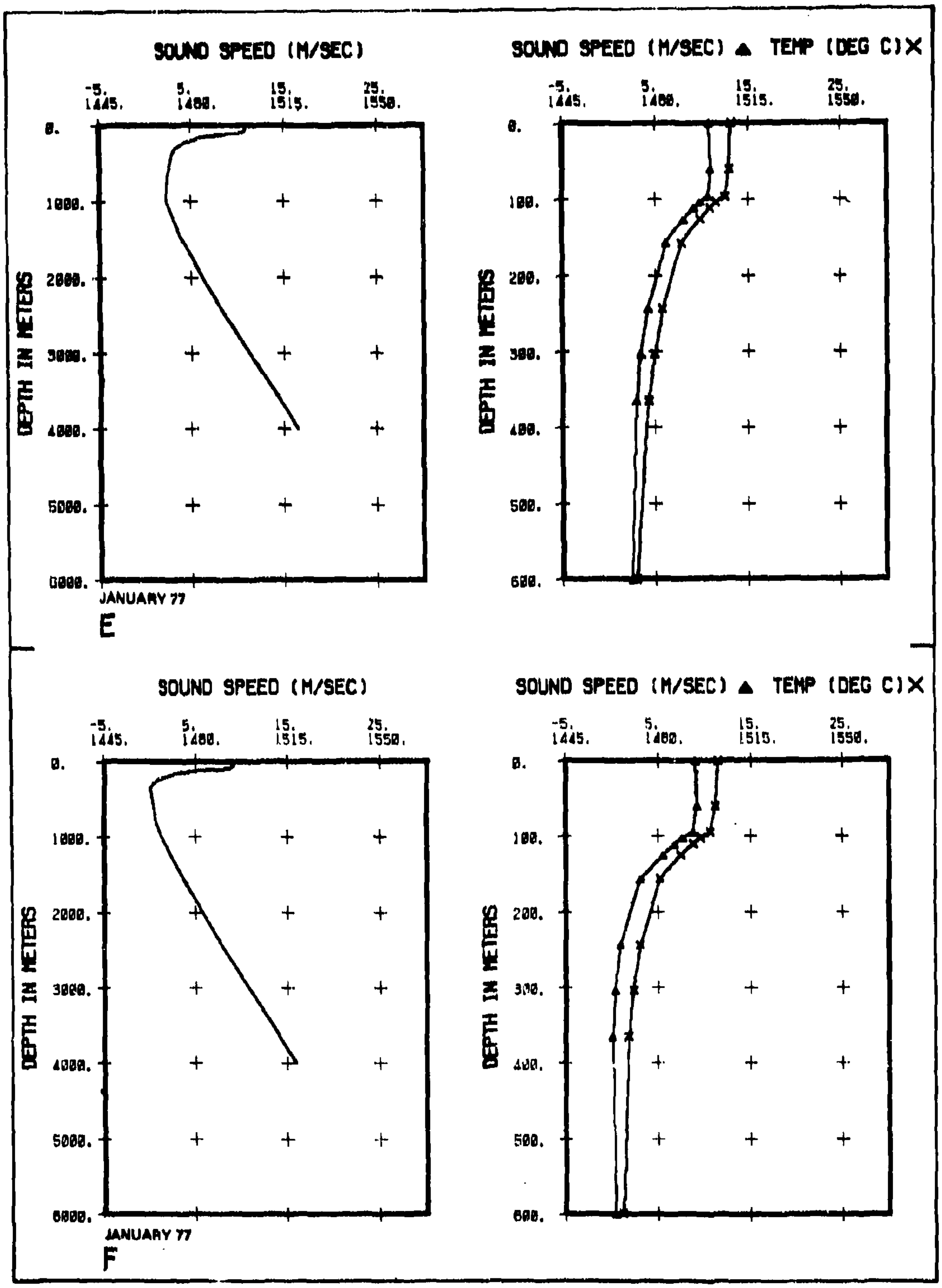


Figure C-14 continued.



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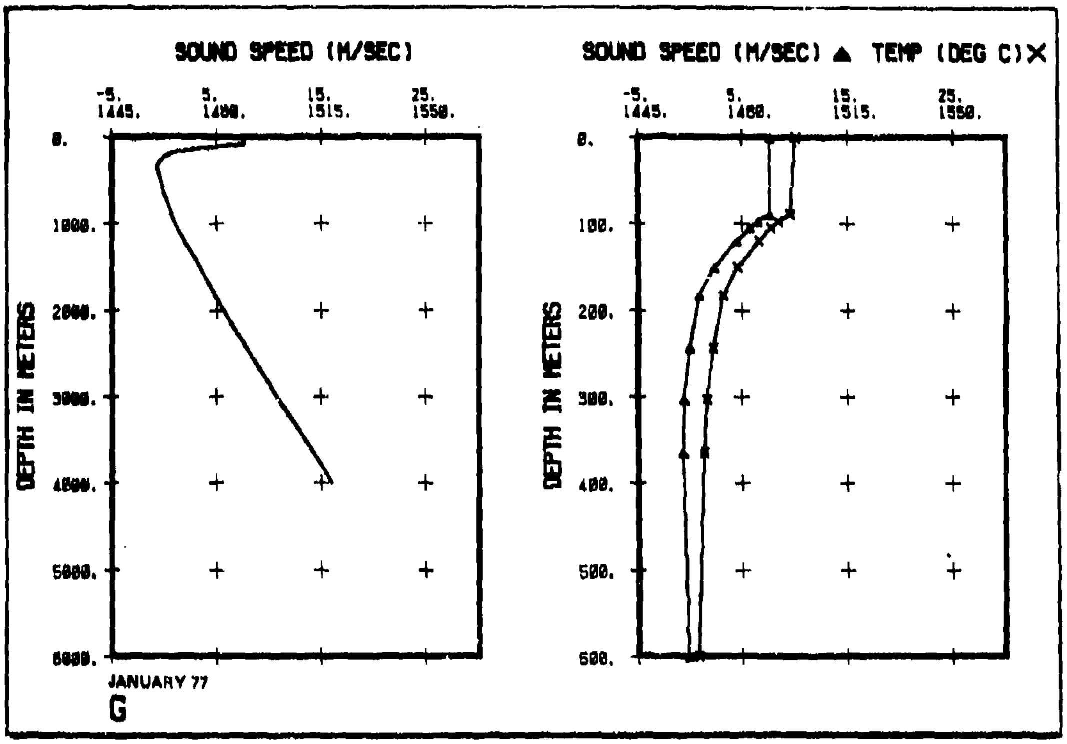

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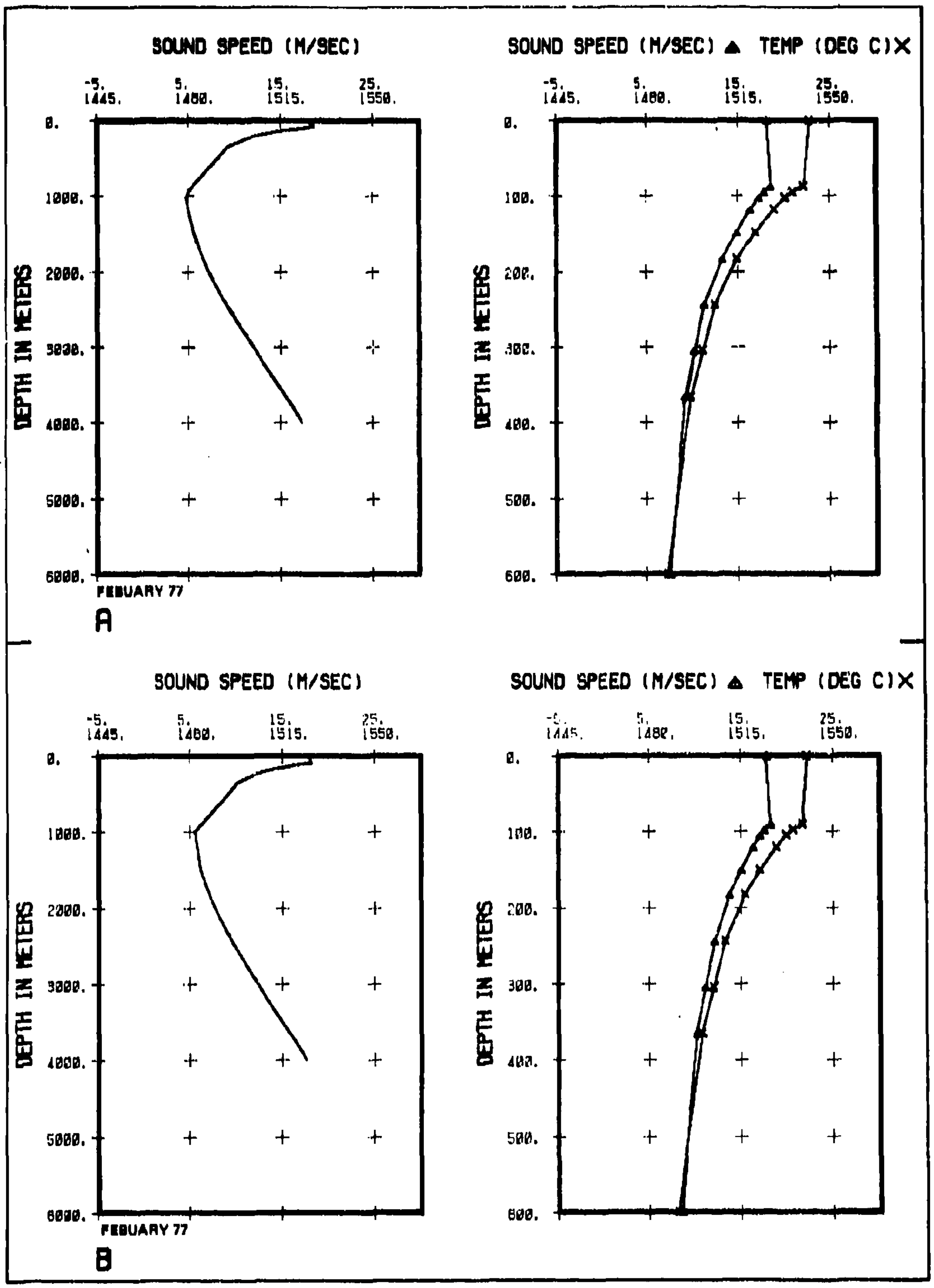
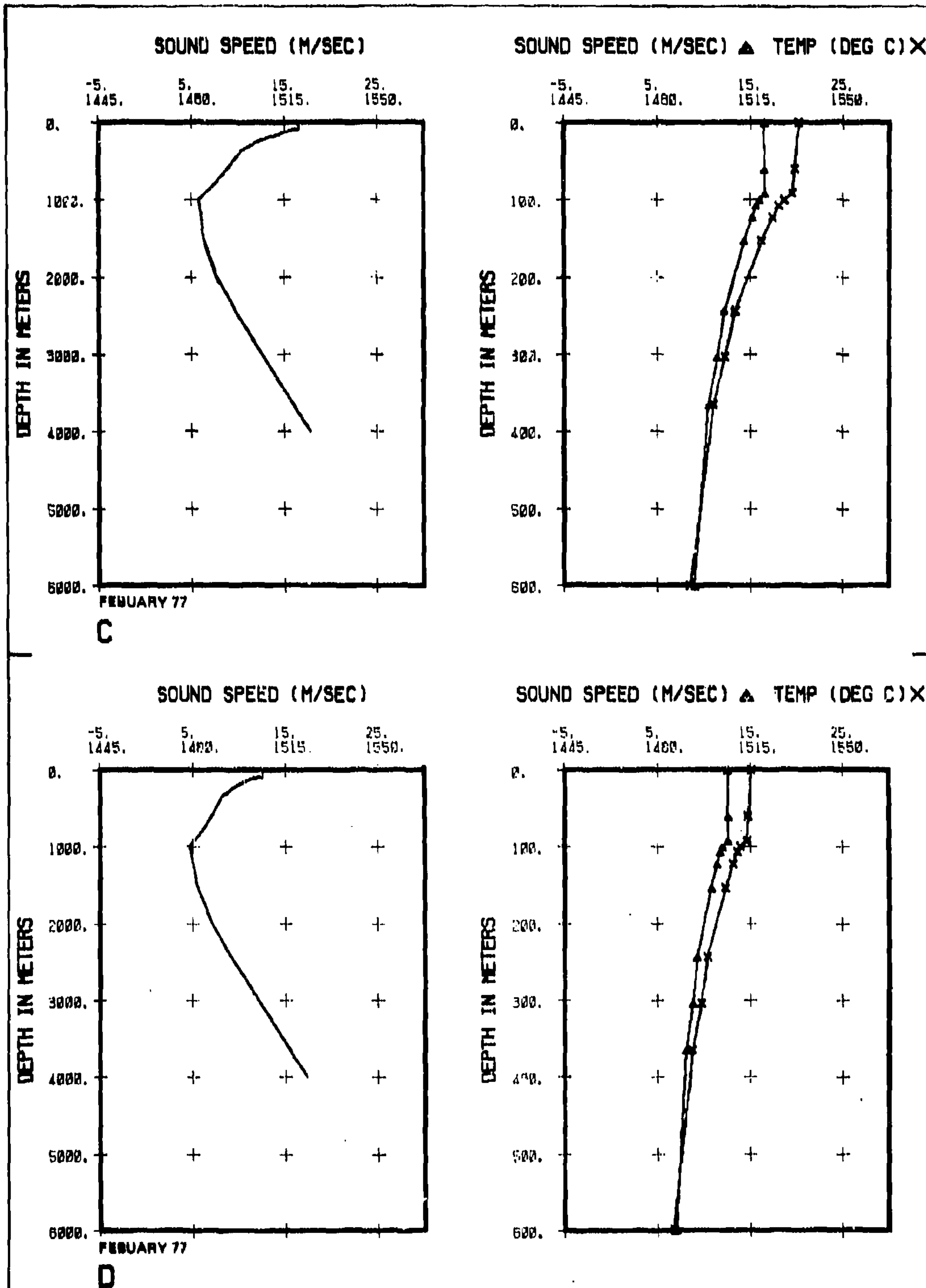


Figure C-15. Profiles for February.



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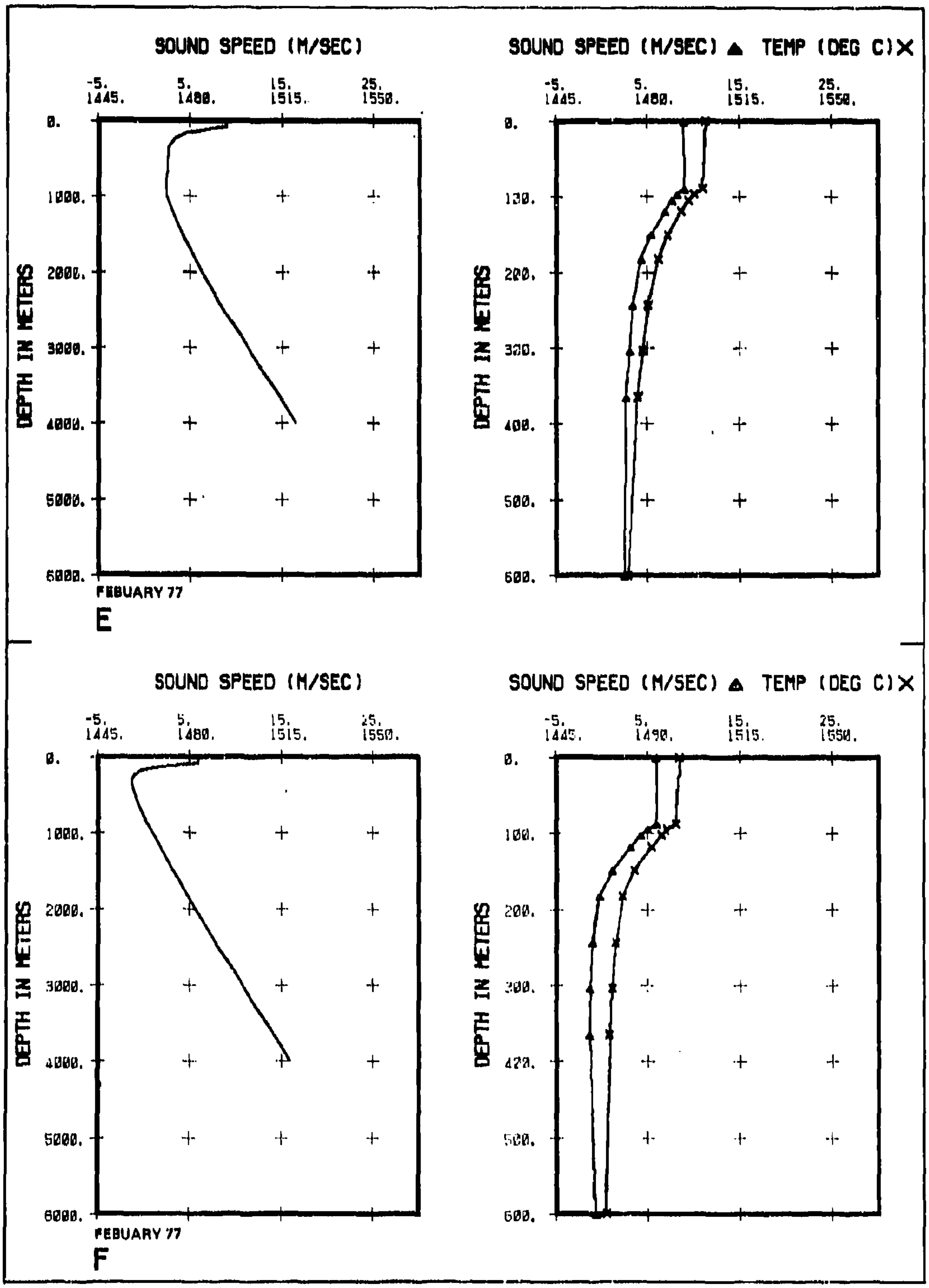

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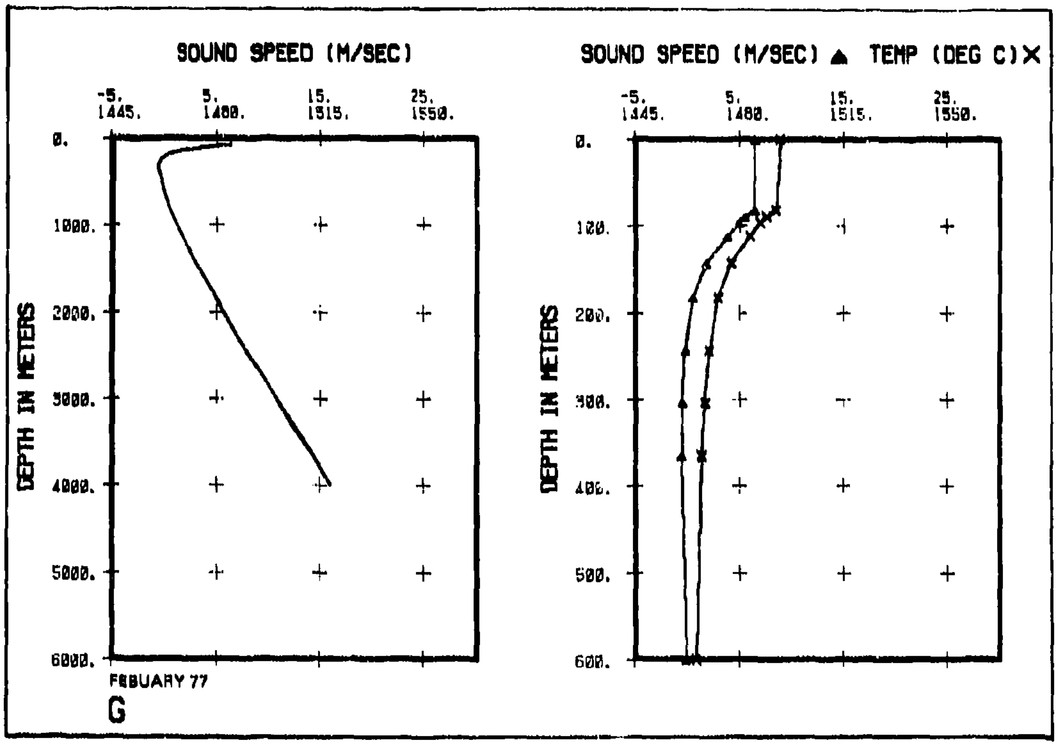

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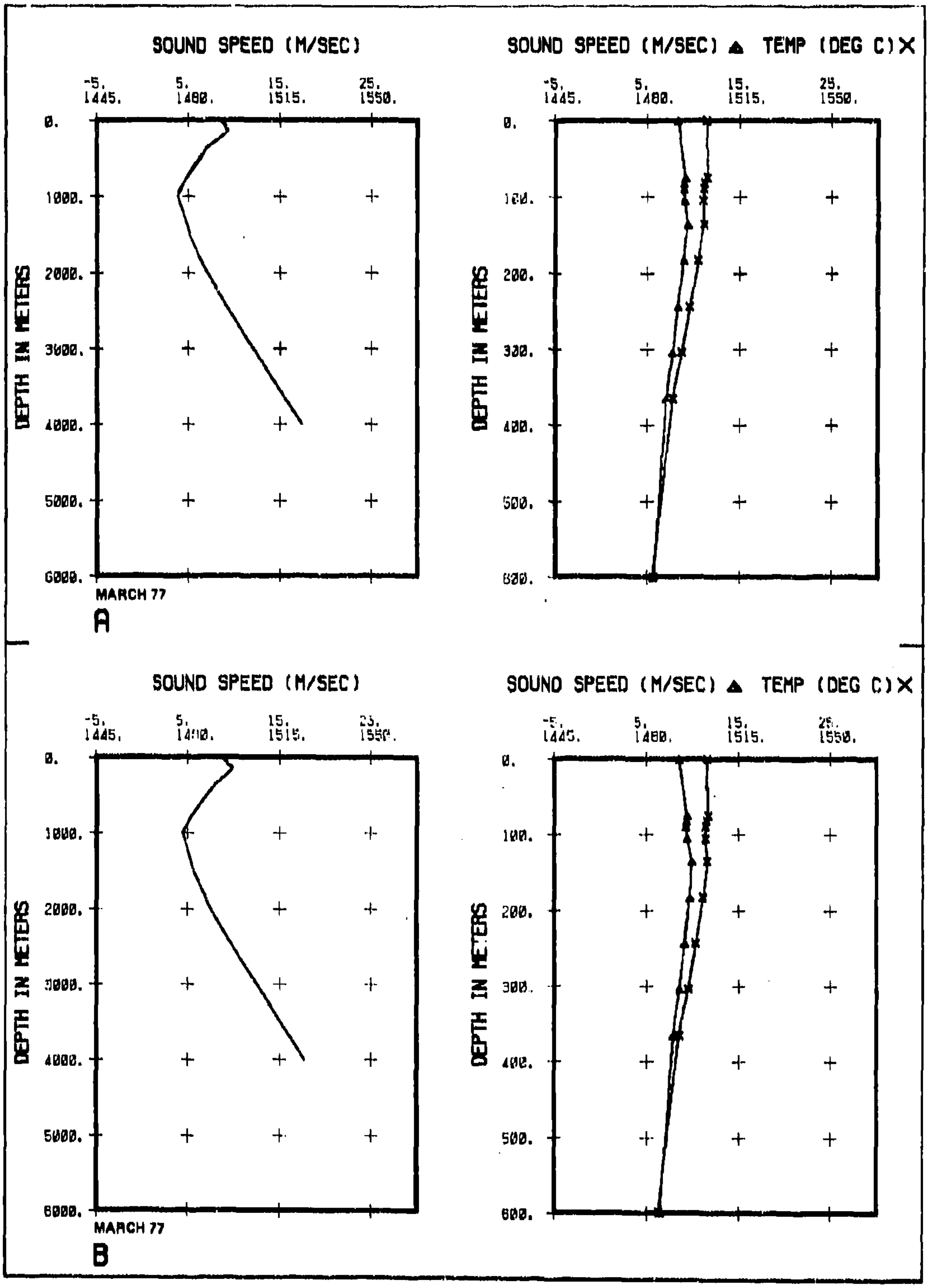


Figure C-16. Profiles for March.

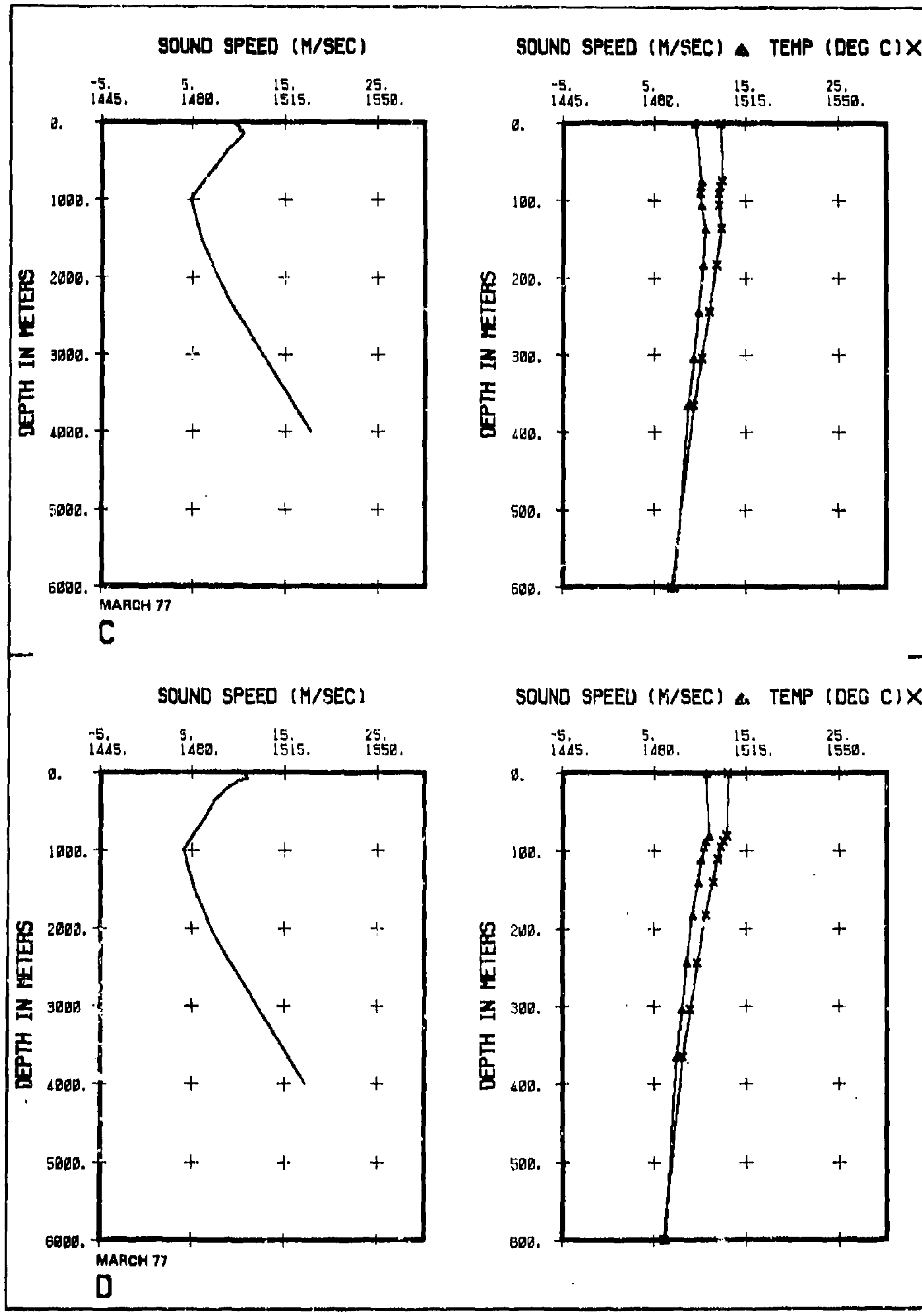
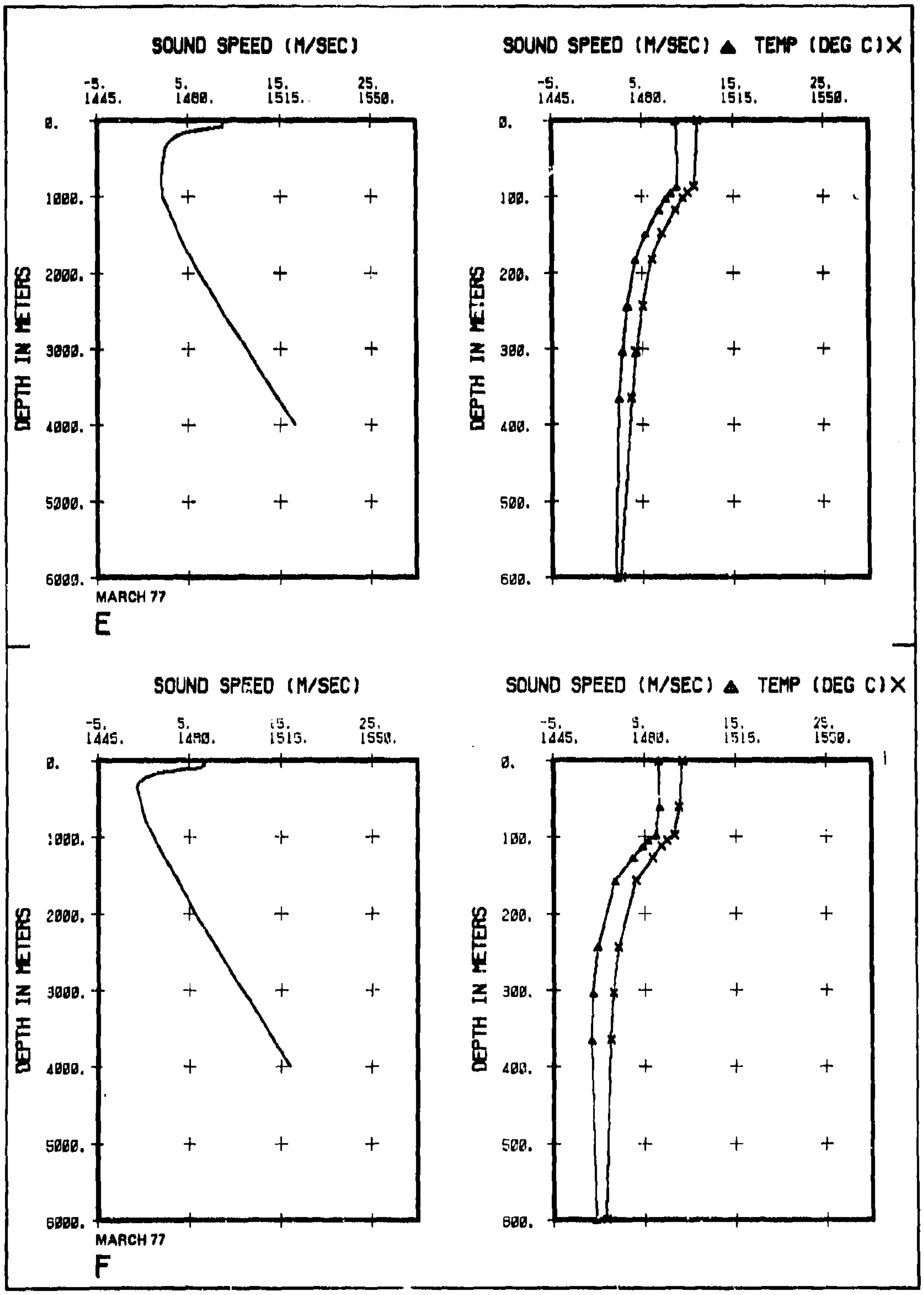


Figure C-16 continued.



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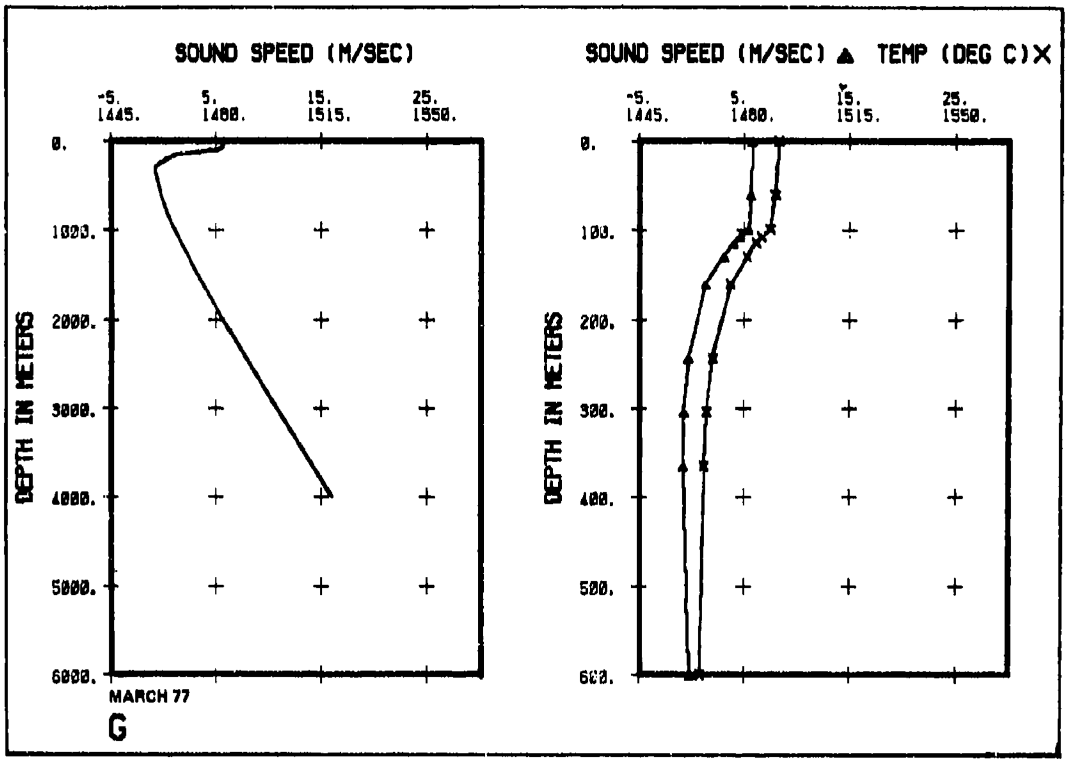

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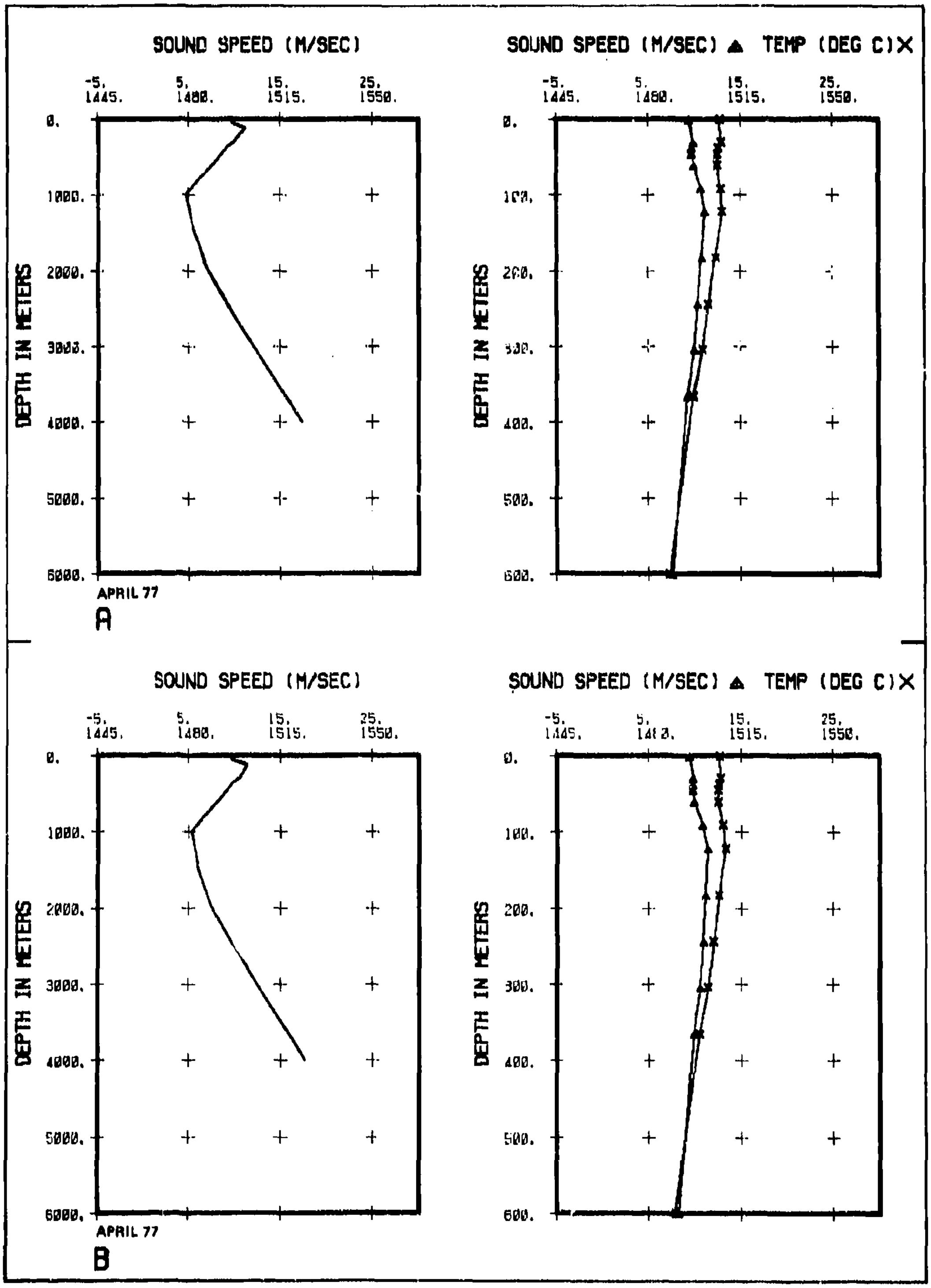


Figure C-17. Profiles for April.

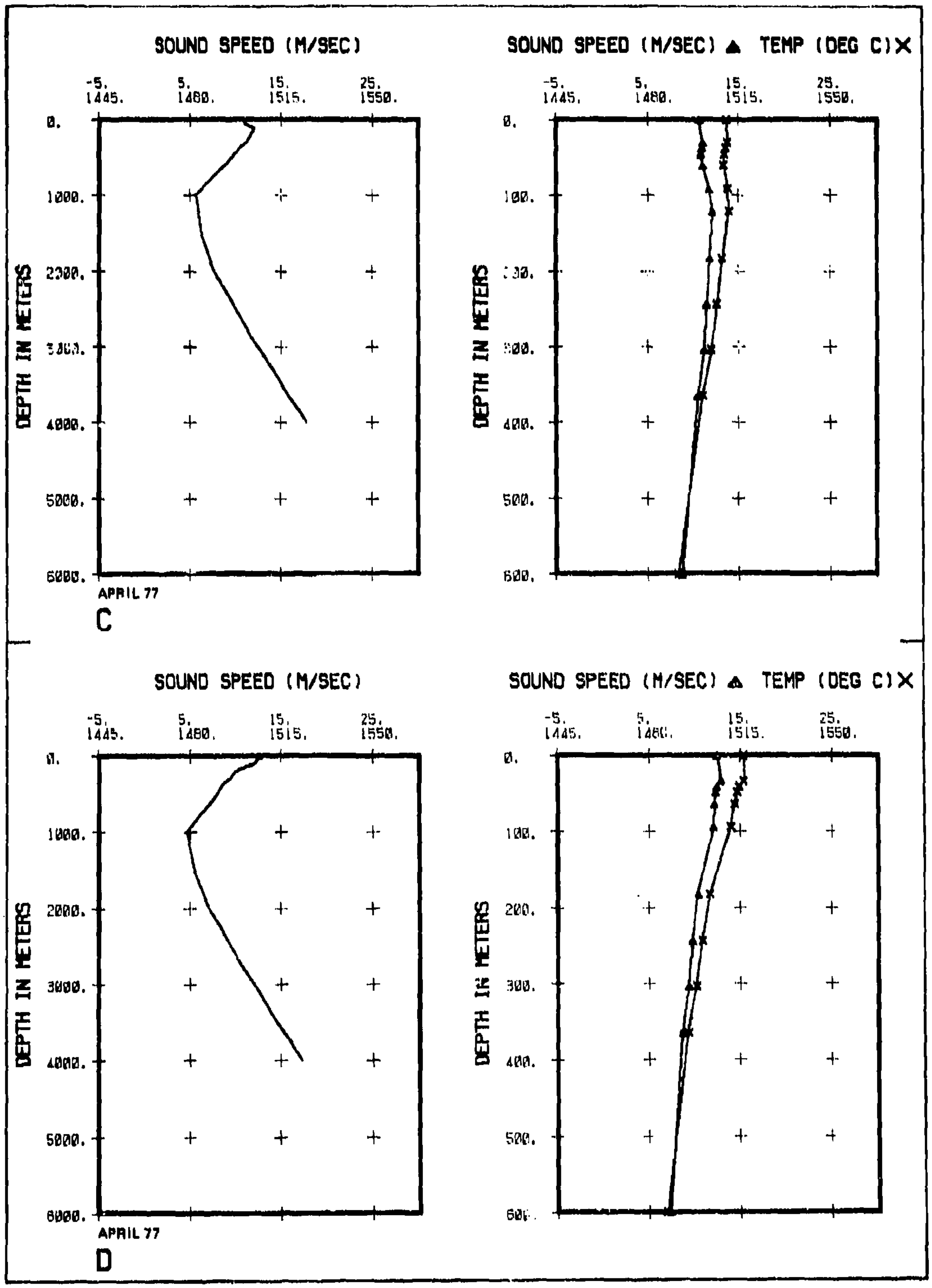
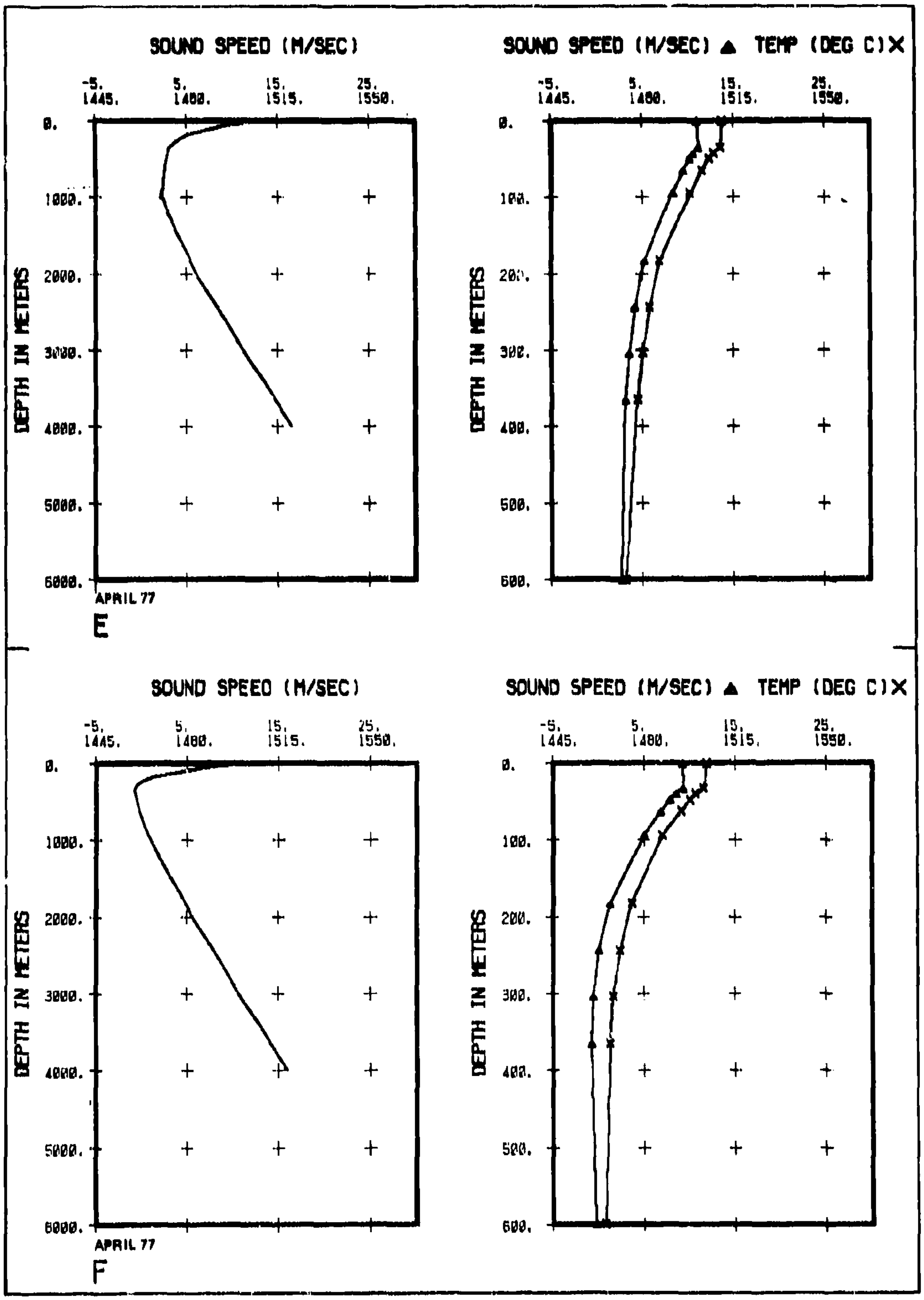


Figure C-17 continued.



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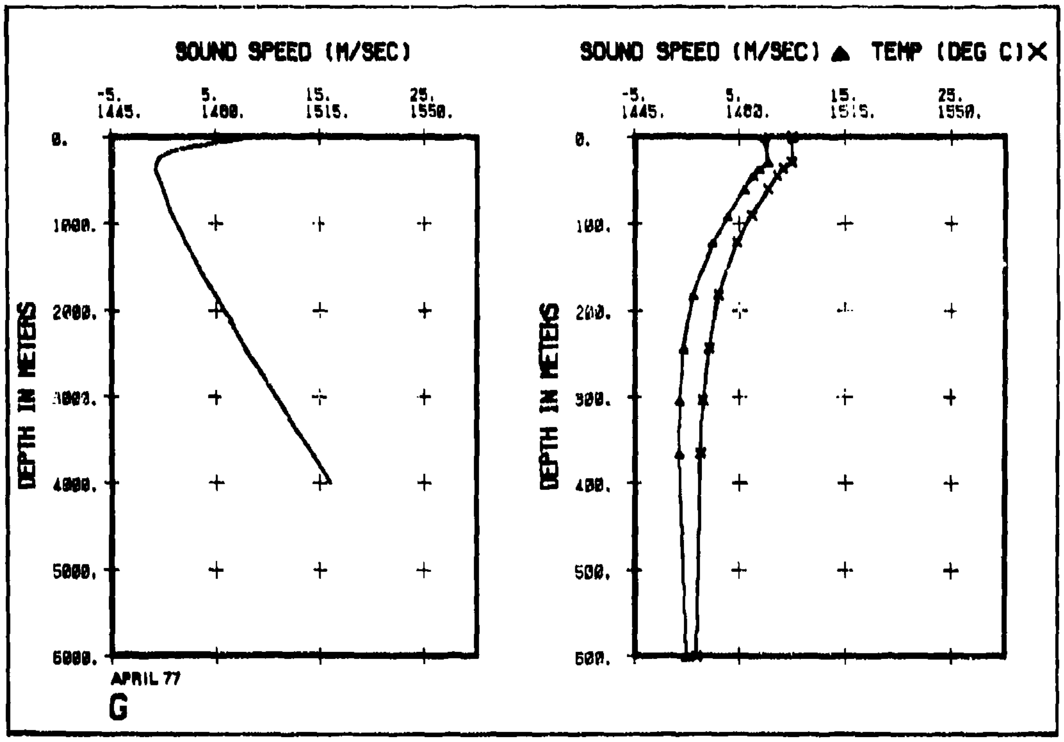

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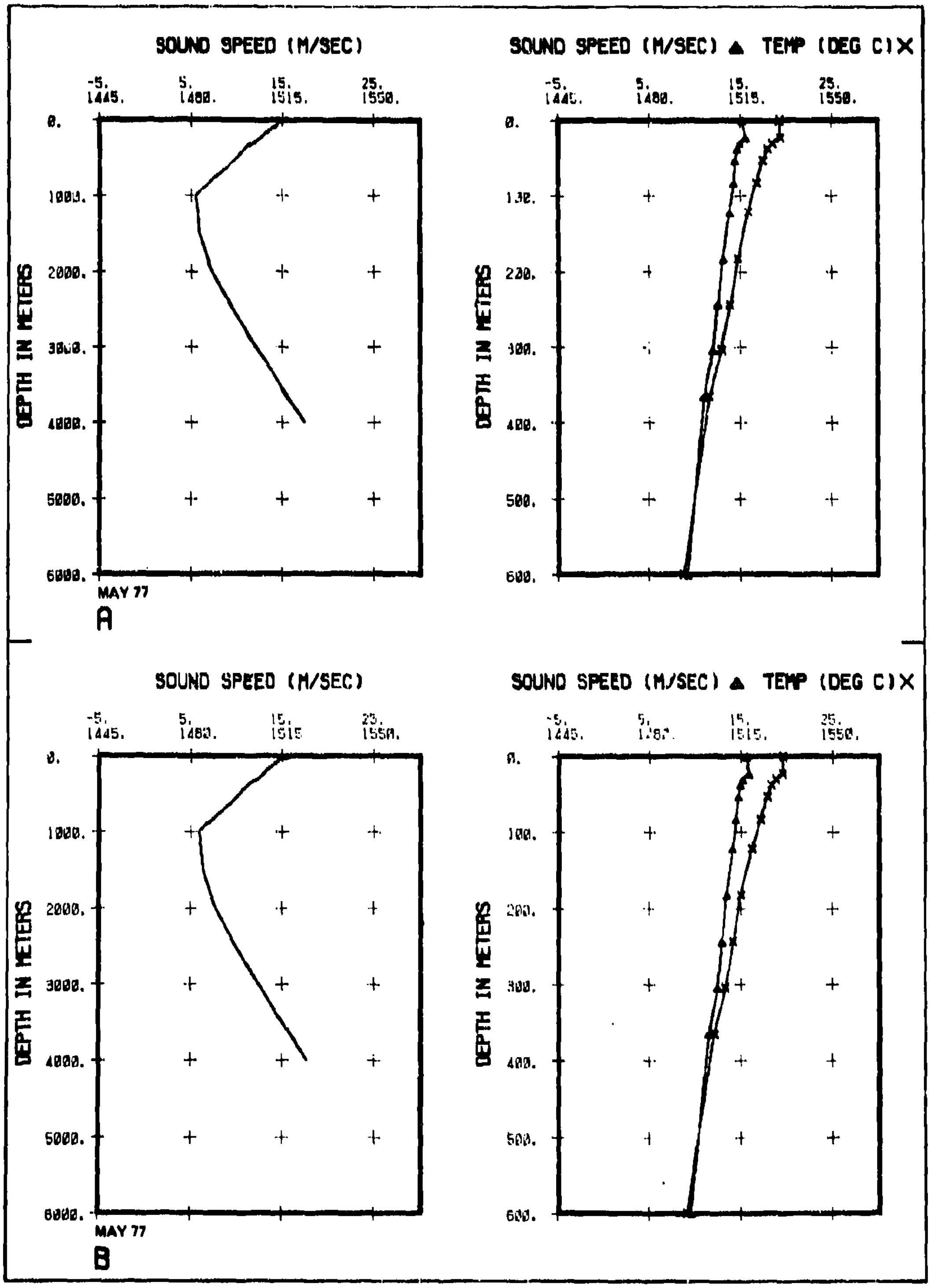
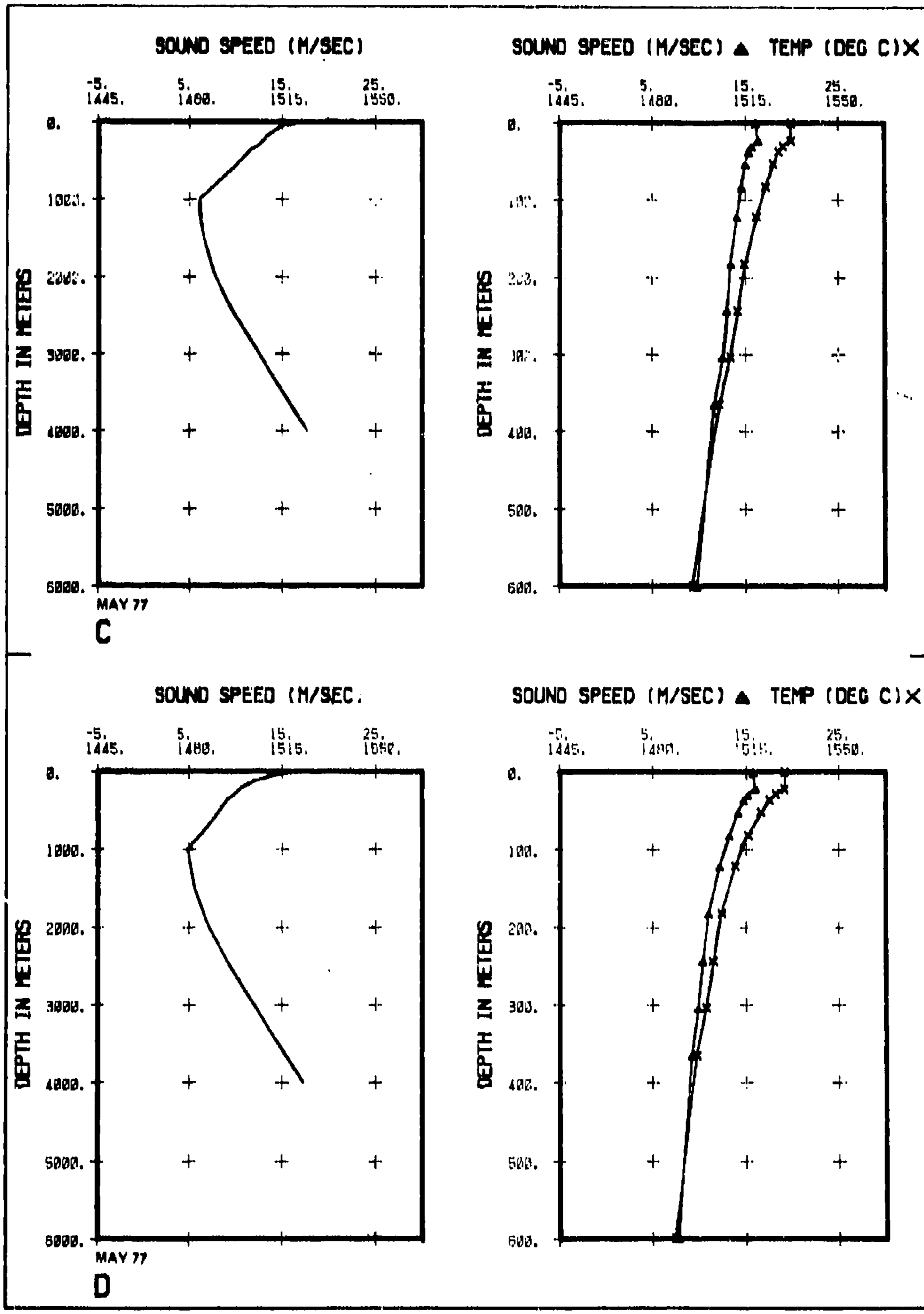


Figure C-18. Profiles for May.



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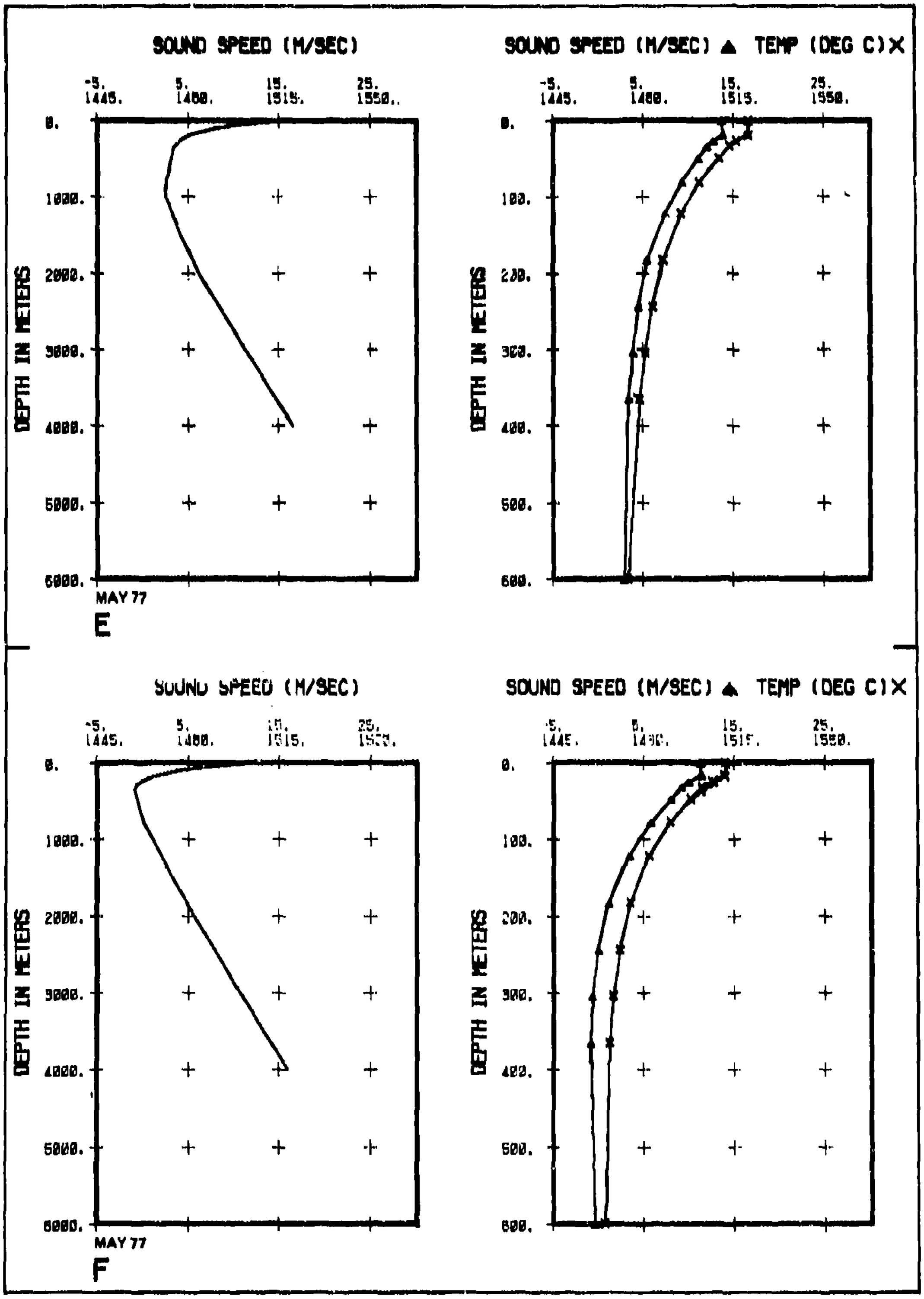

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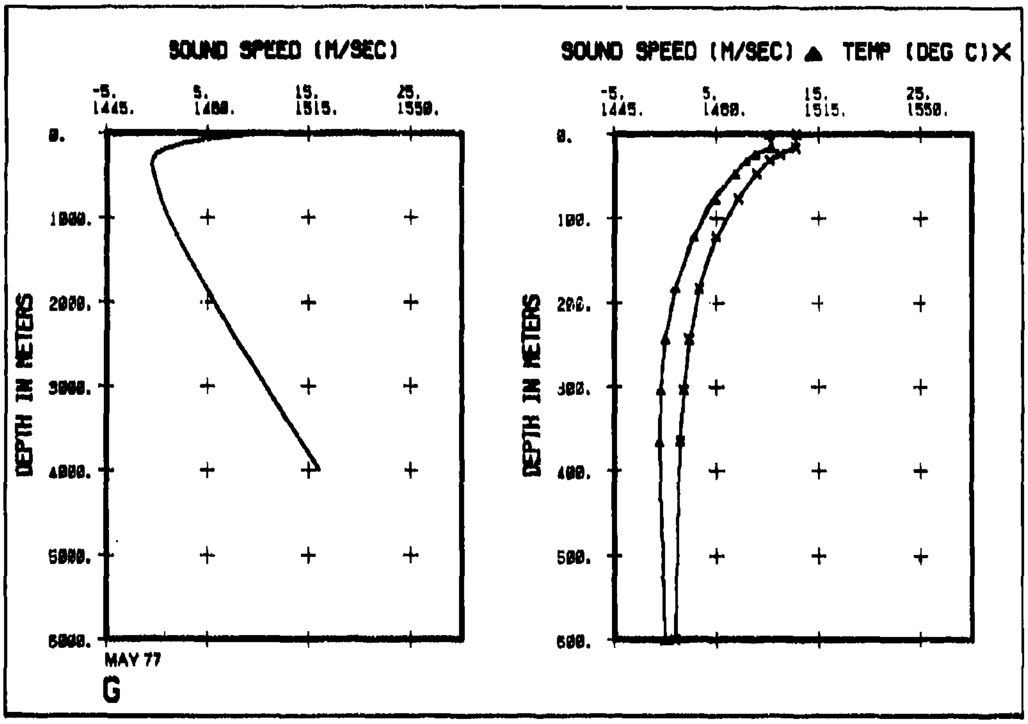

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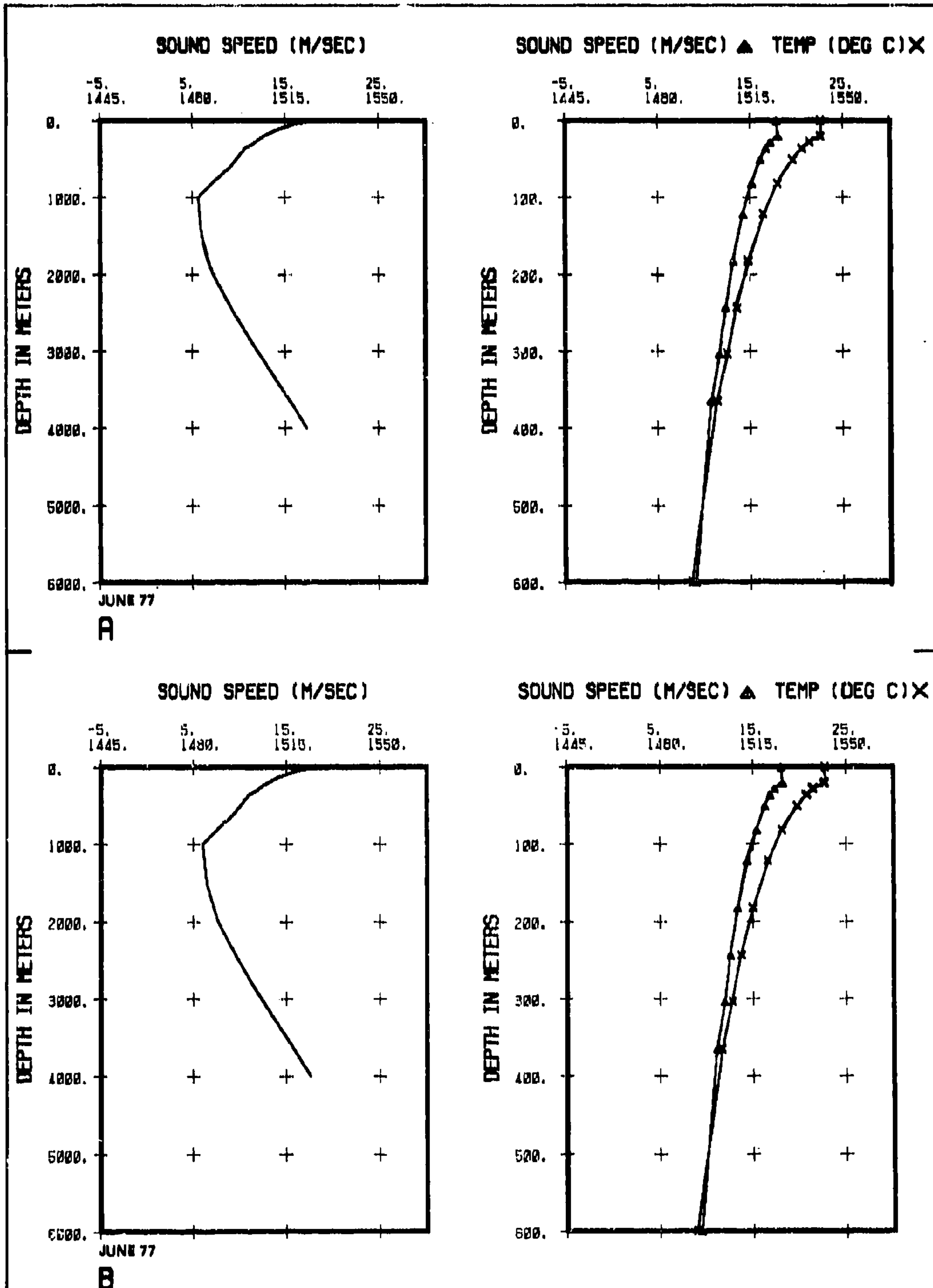


Figure C-19. Profiles for June.

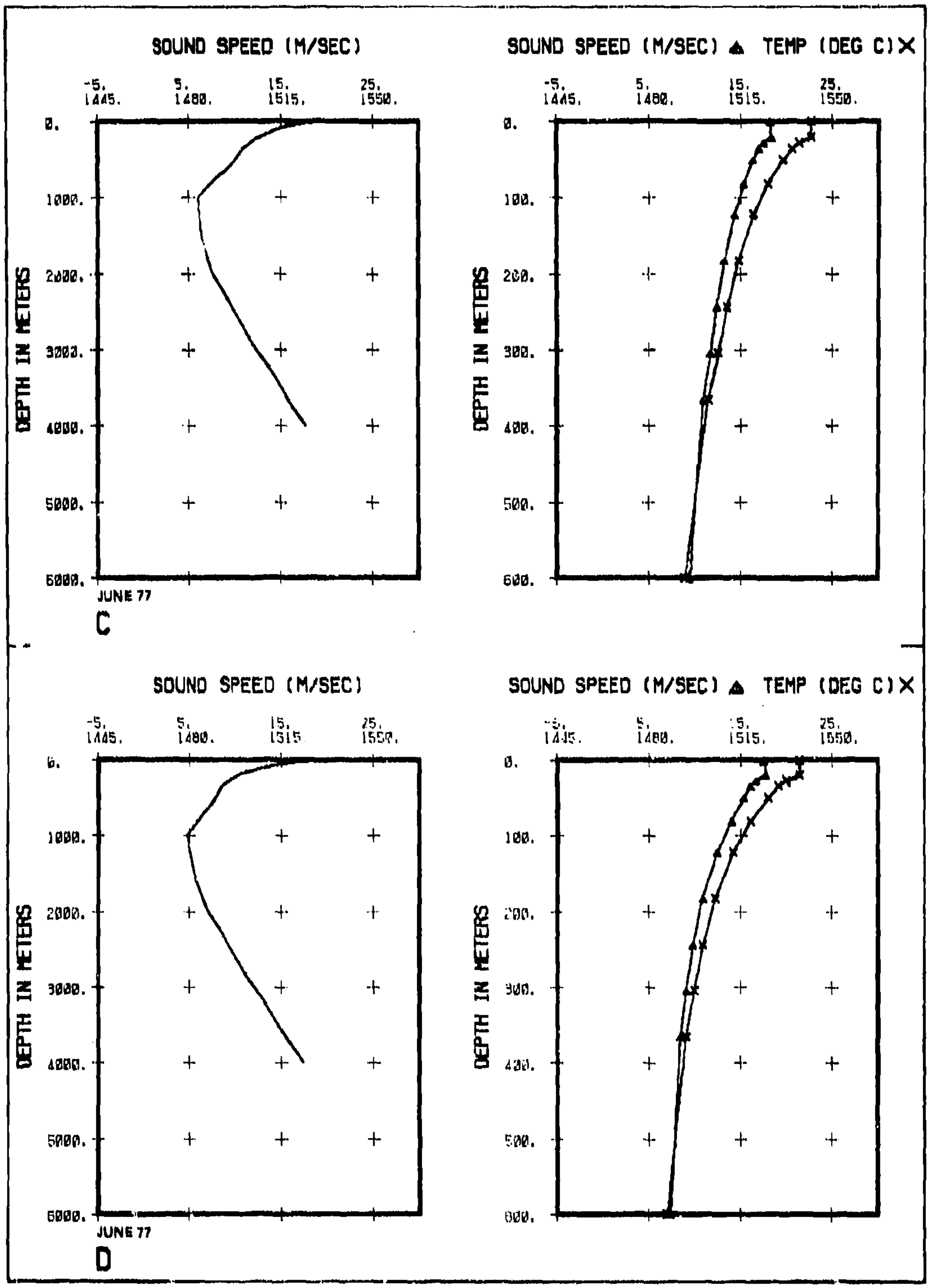
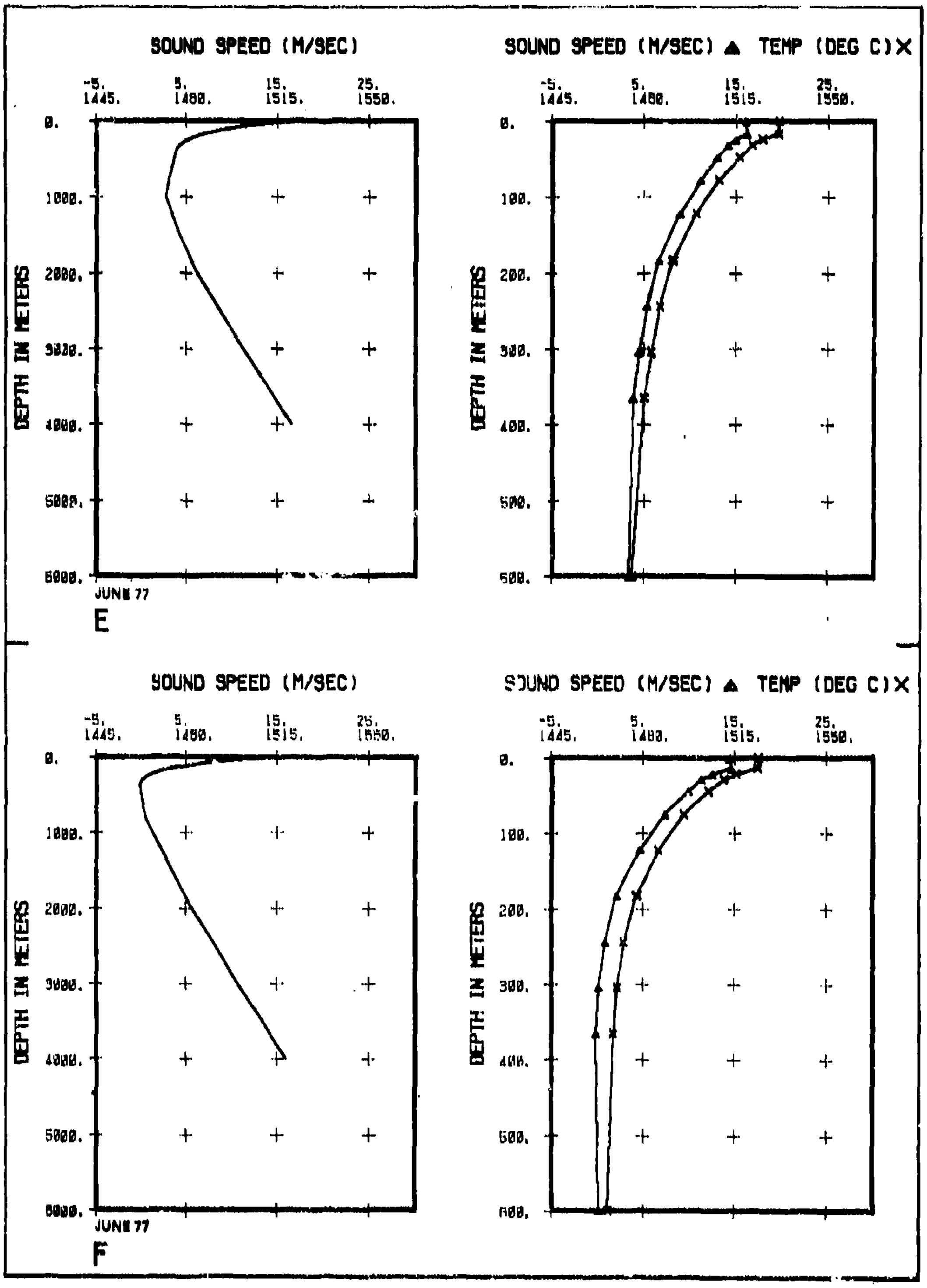


Figure C-19 continued.



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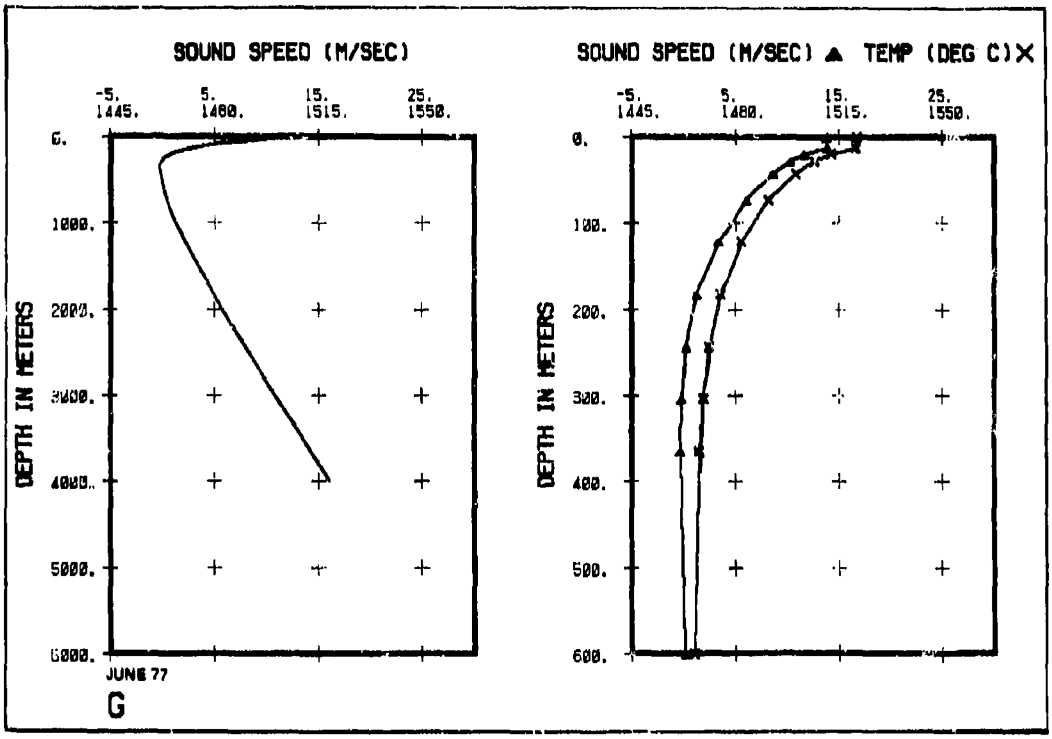

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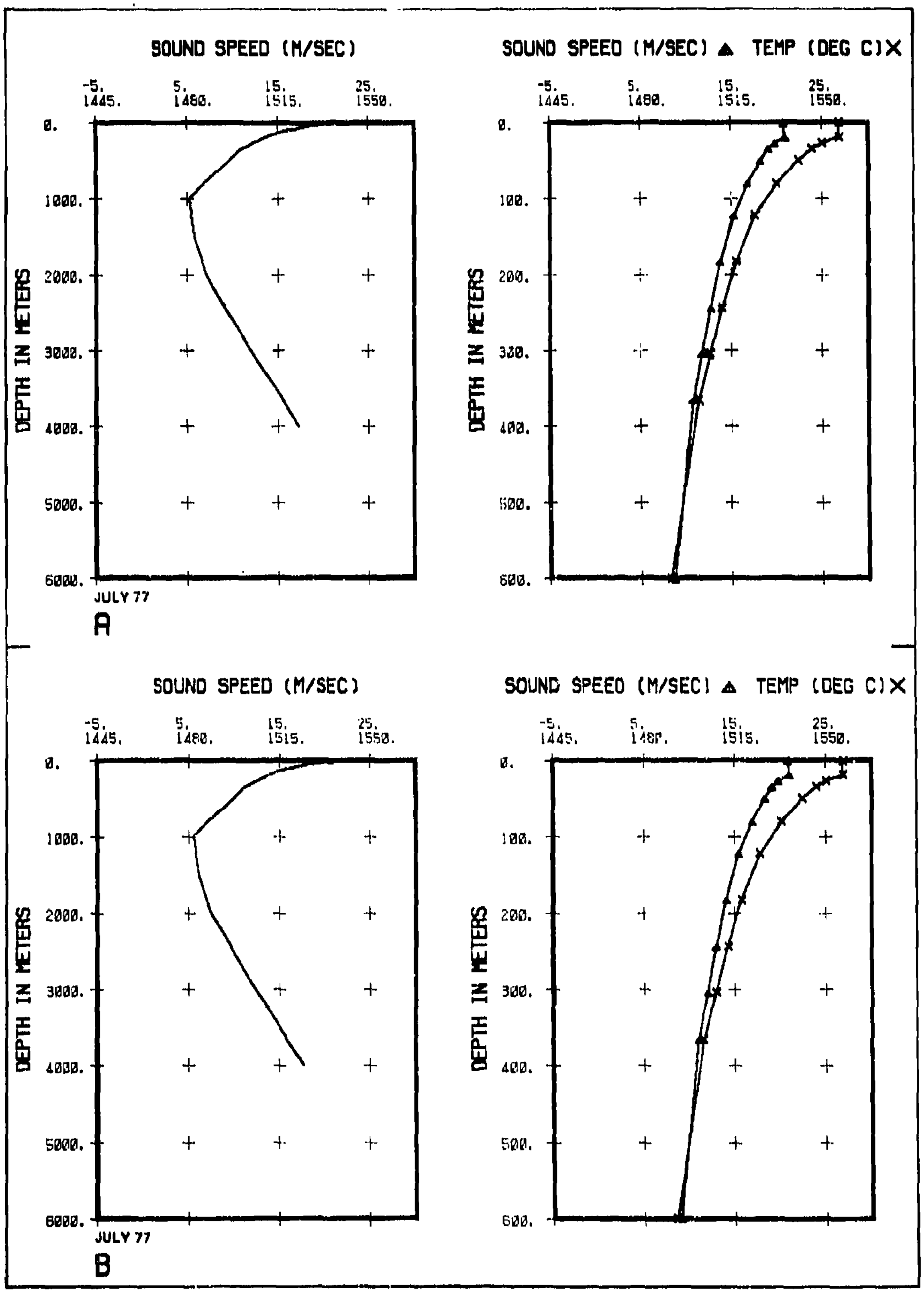


Figure C-20. Profiles for July.

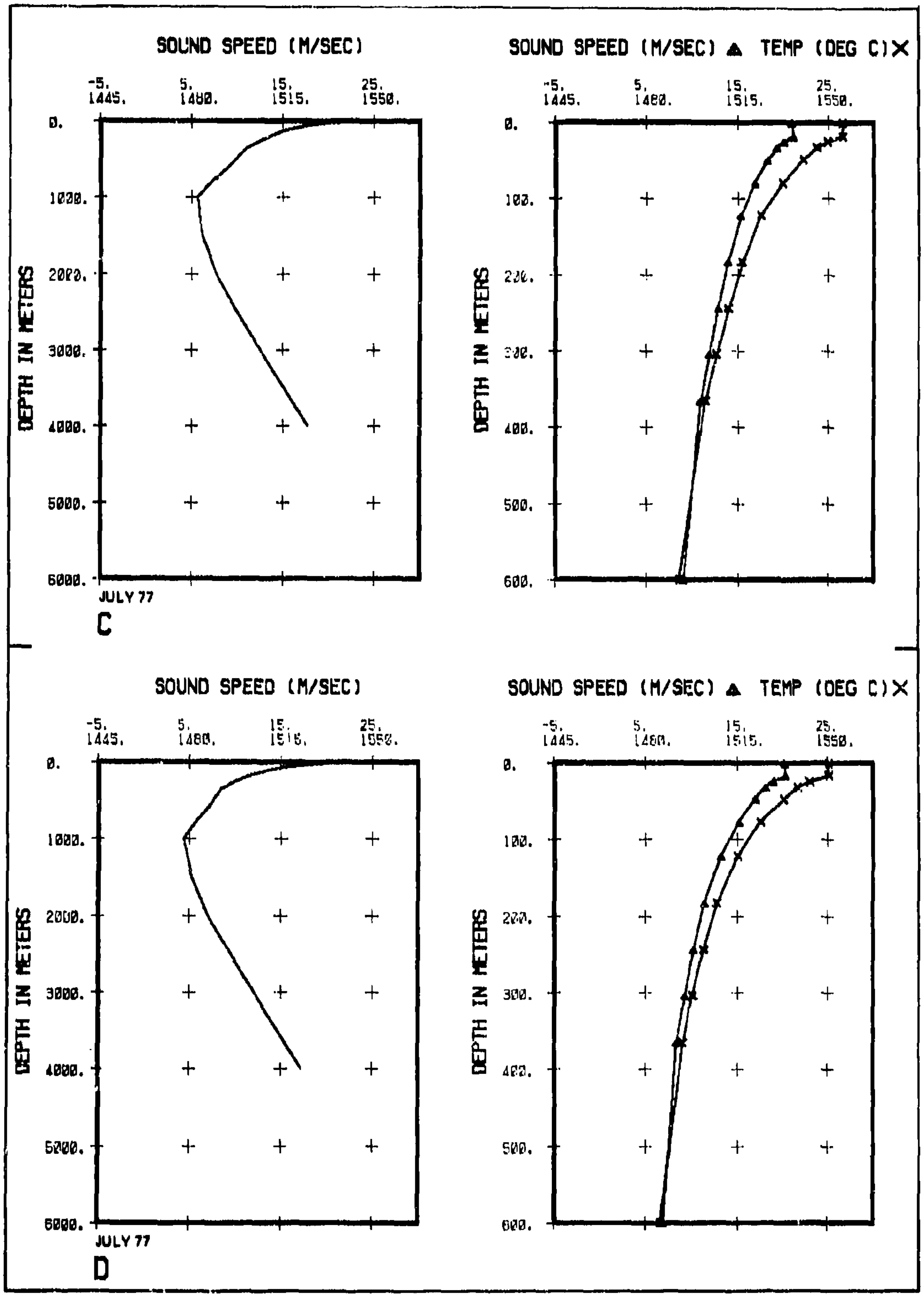
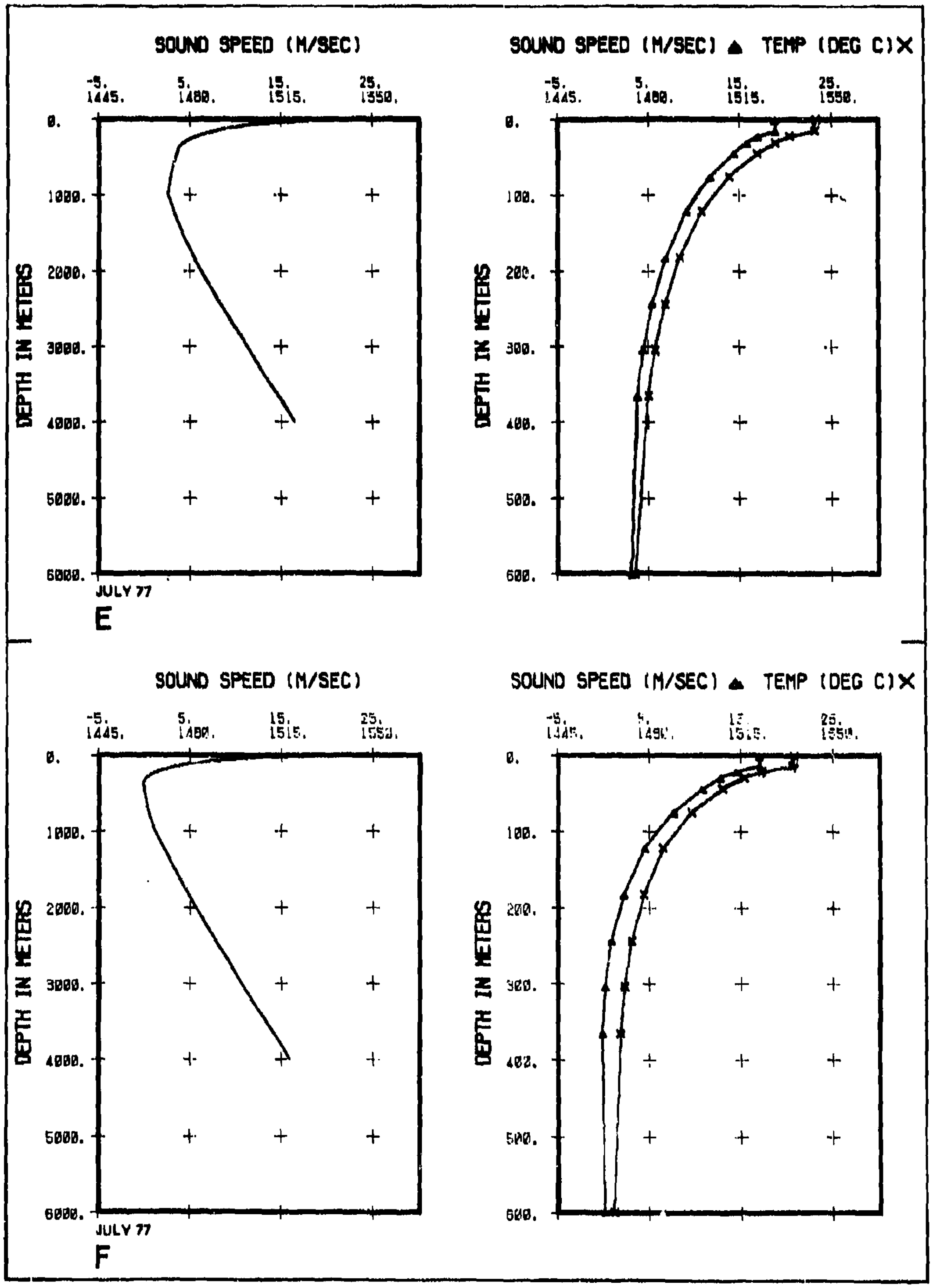


Figure C-20 continued.



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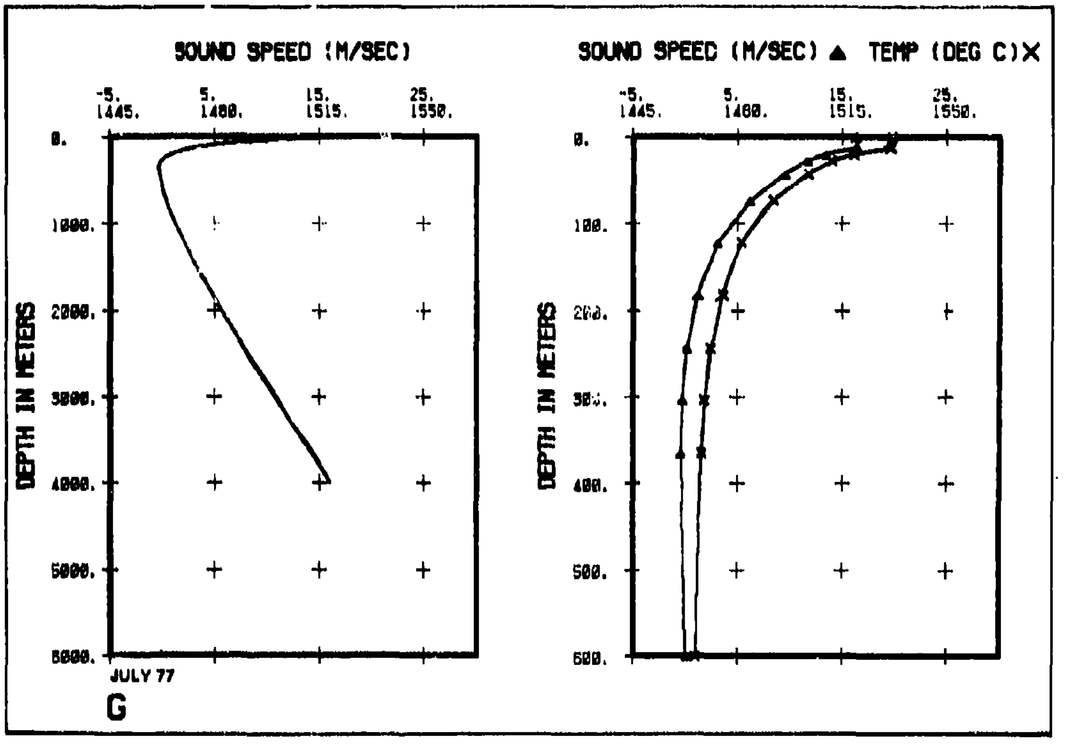

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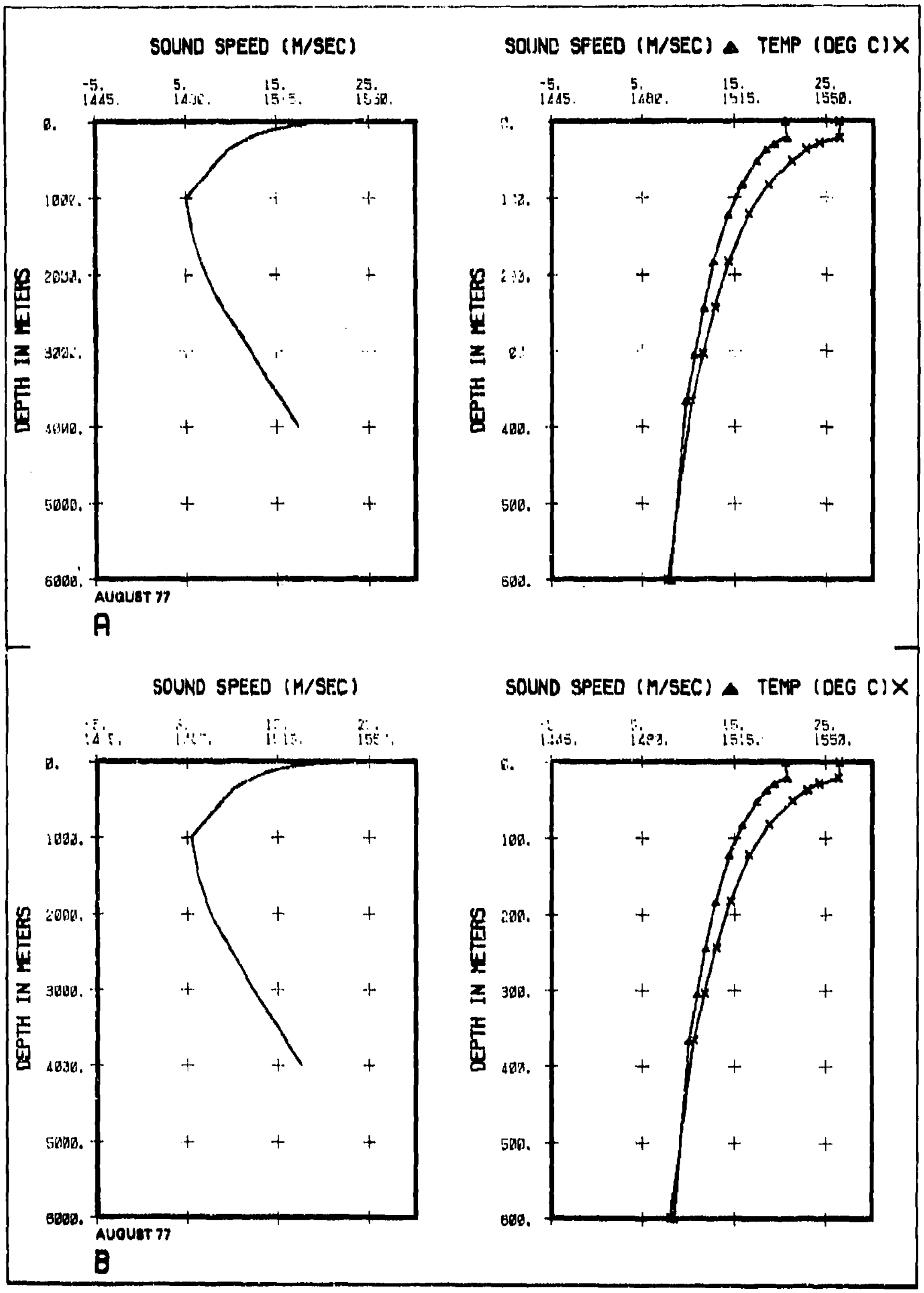


Figure C-21. Profiles for August.

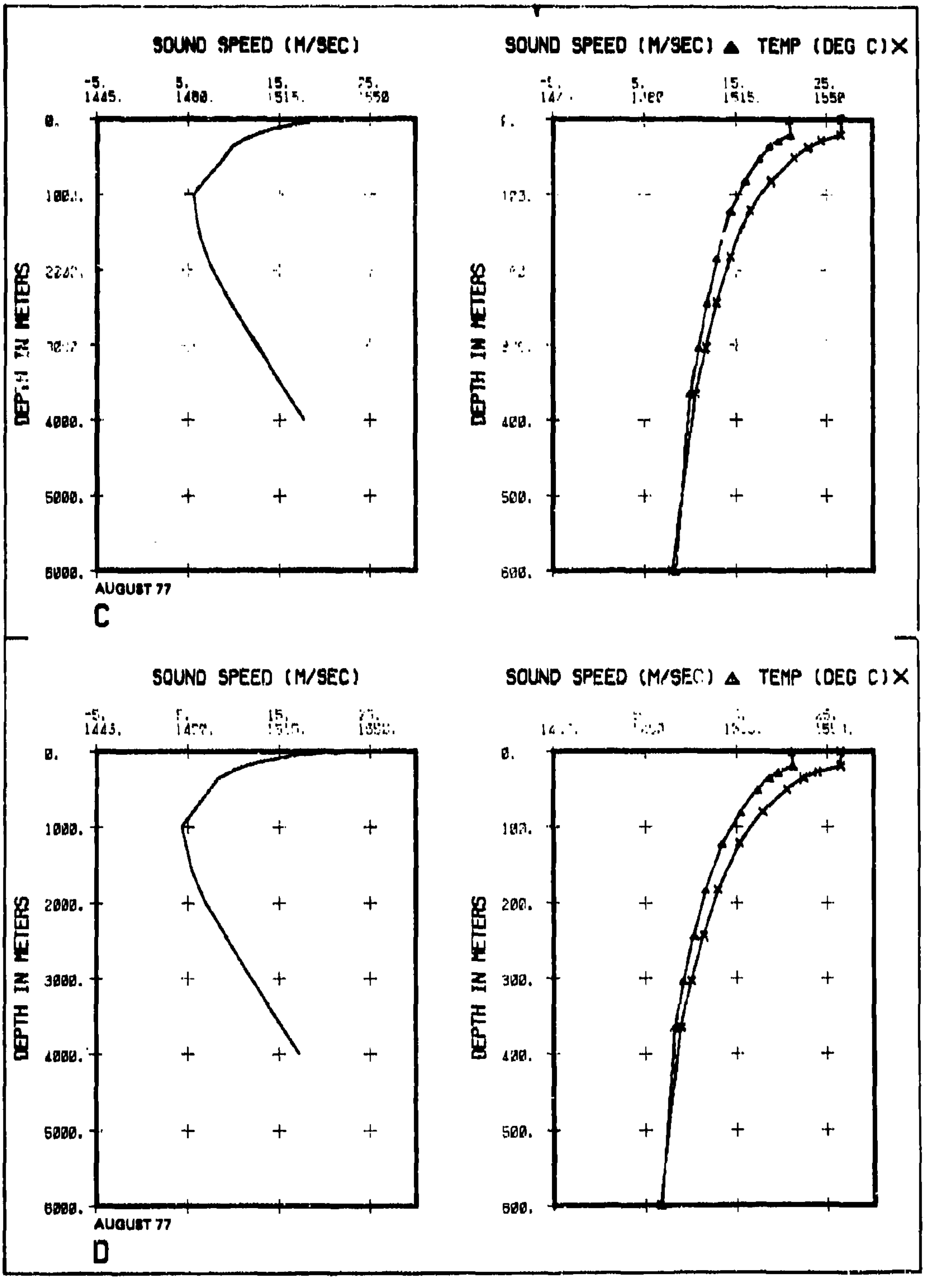
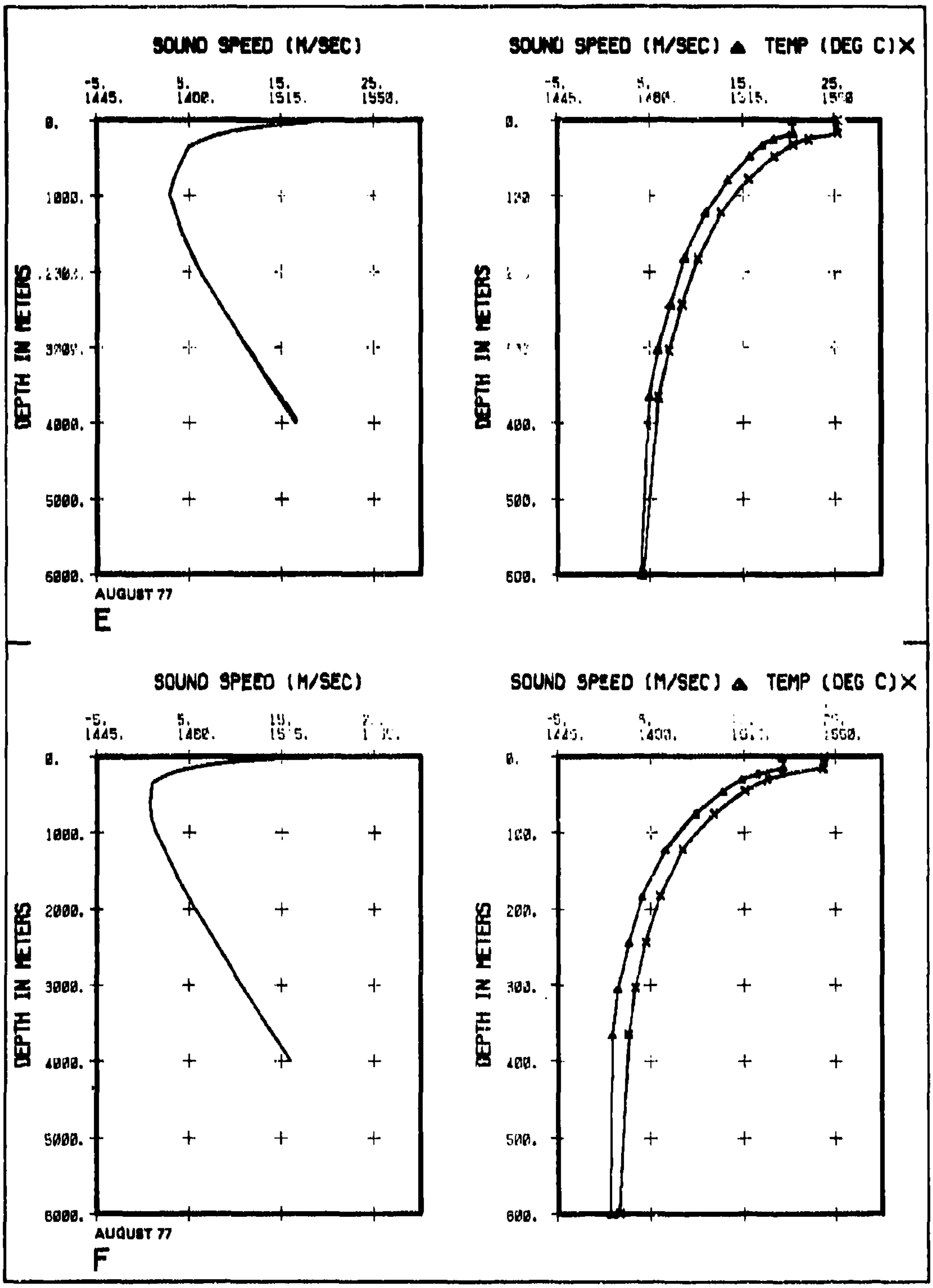


Figure C-21 continued.



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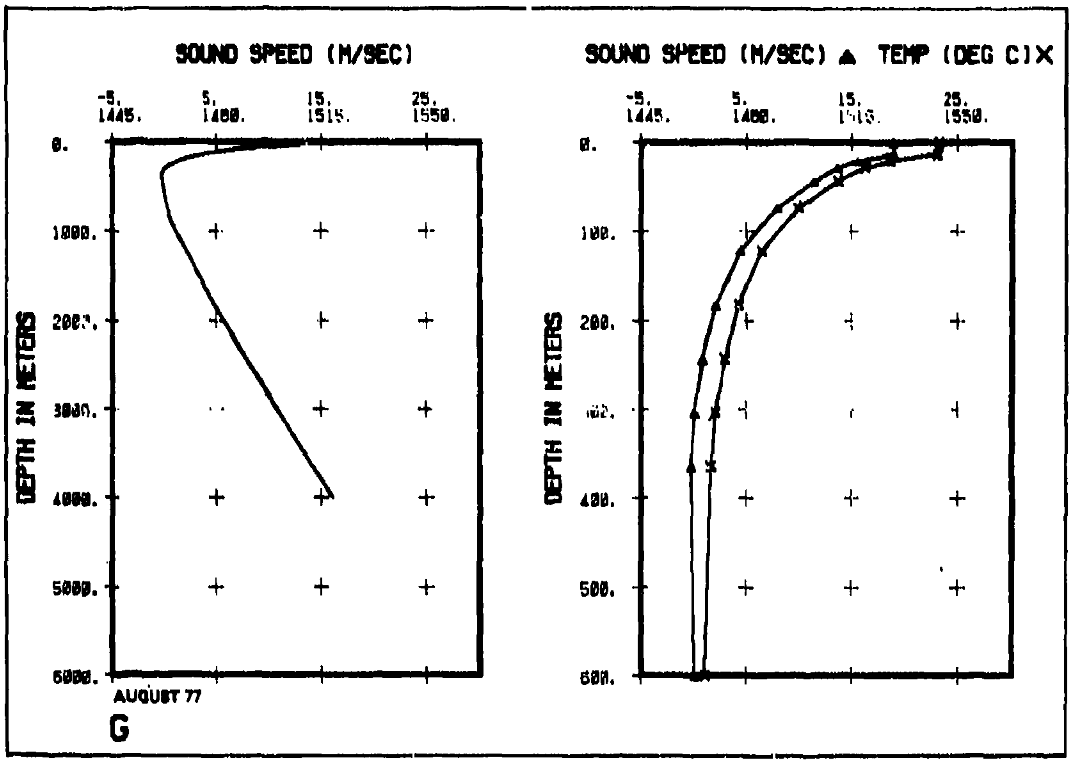

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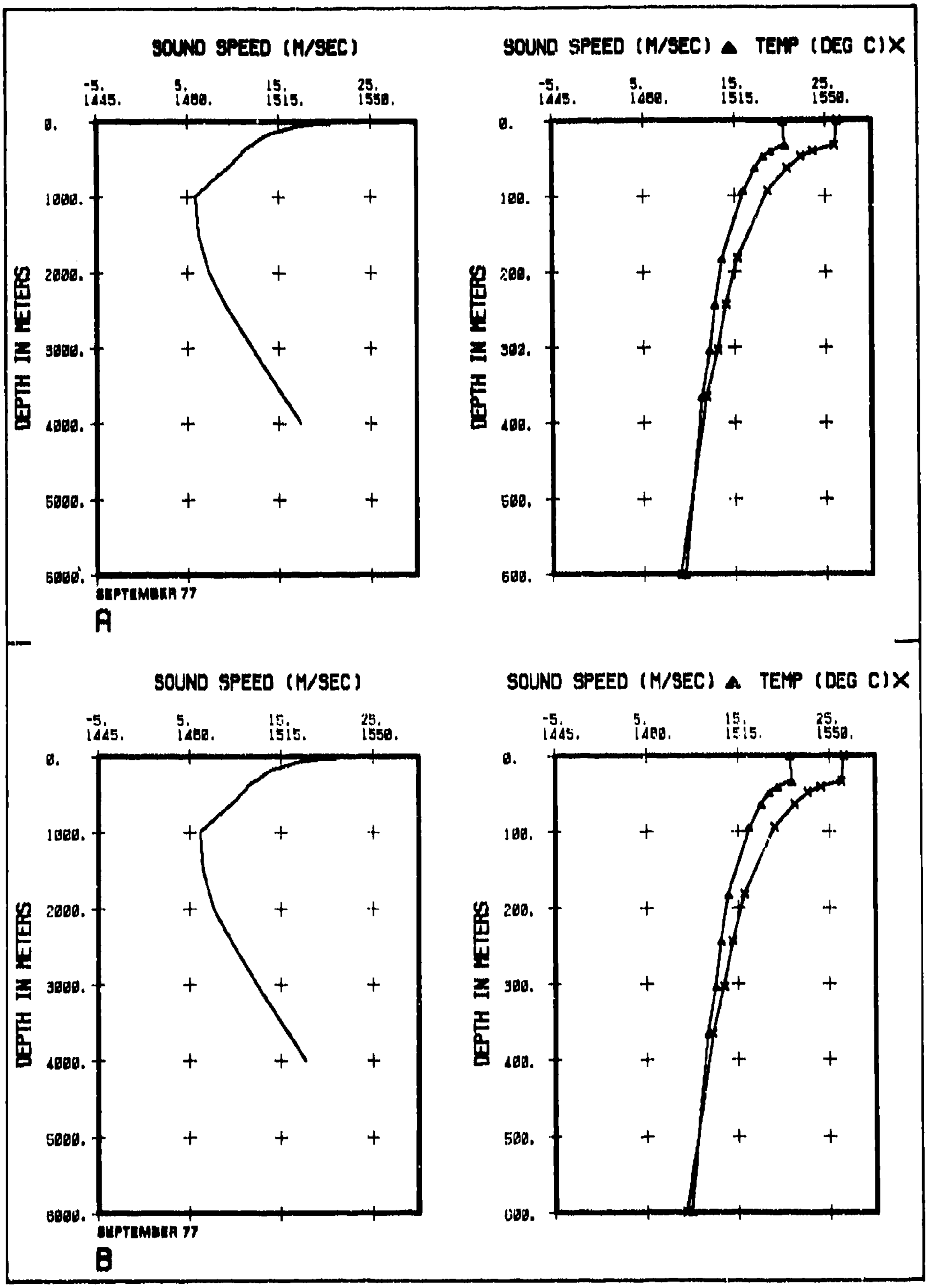


Figure C-22. Profiles for September.

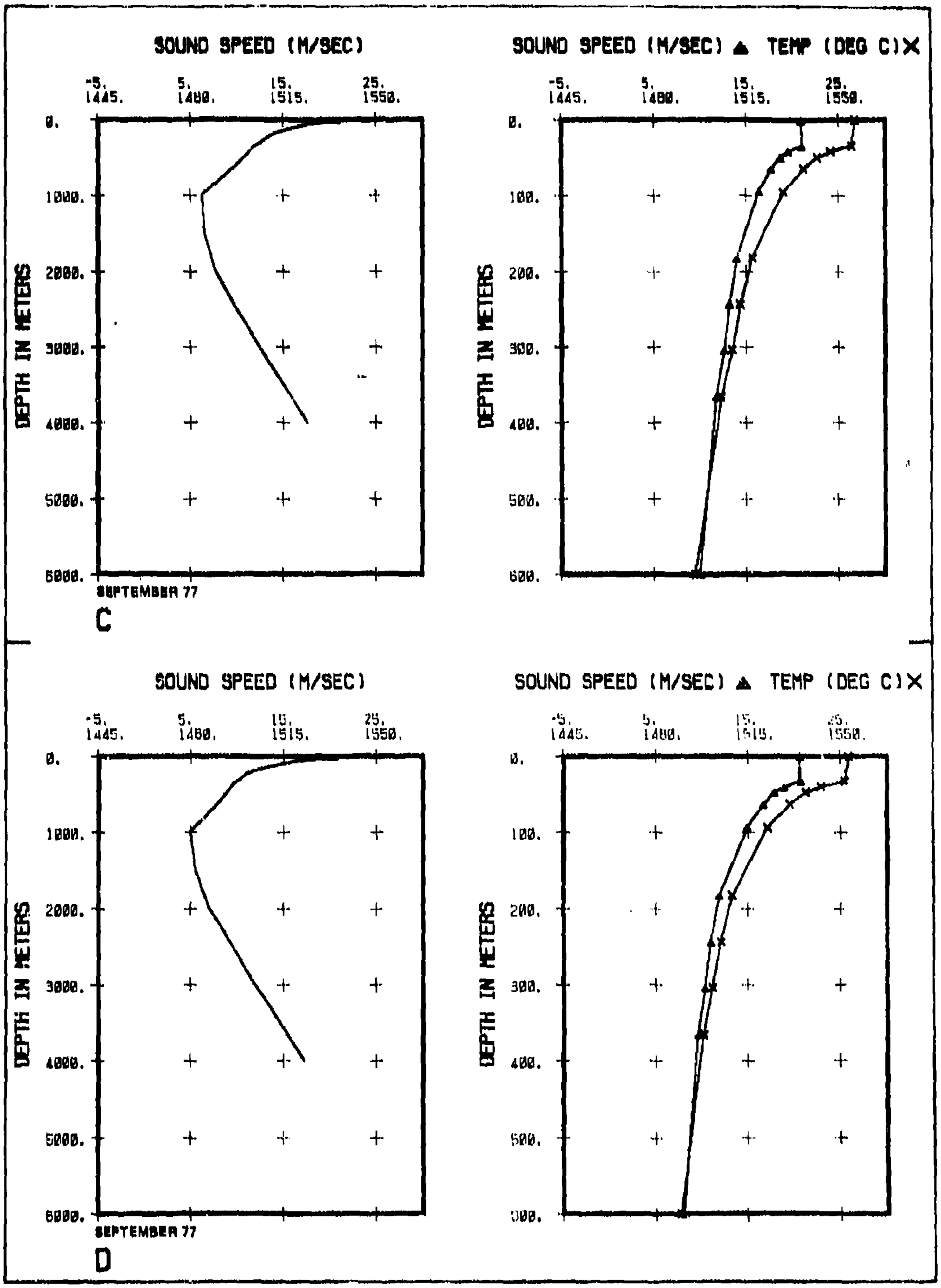
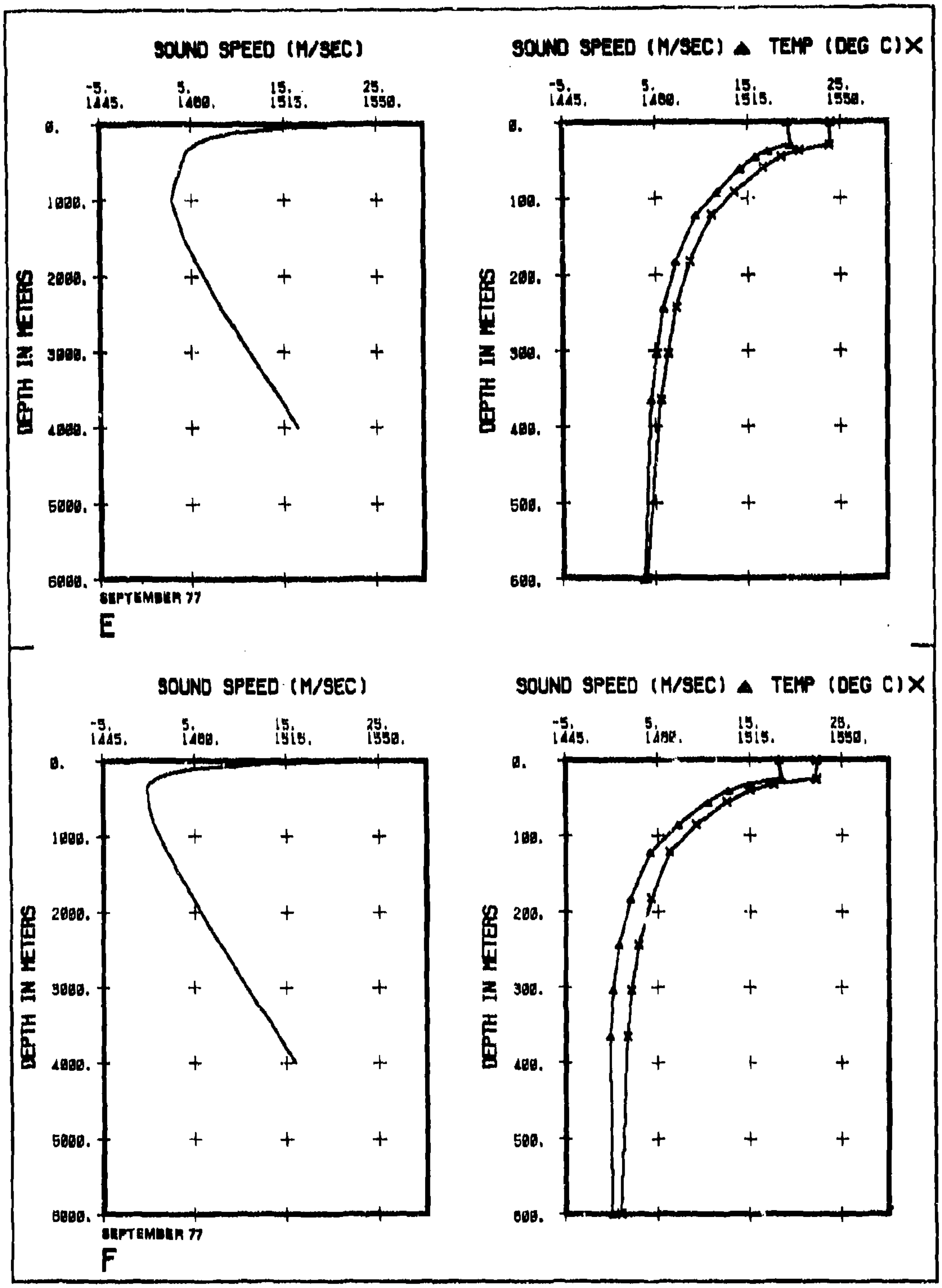


Figure C-22 continued.



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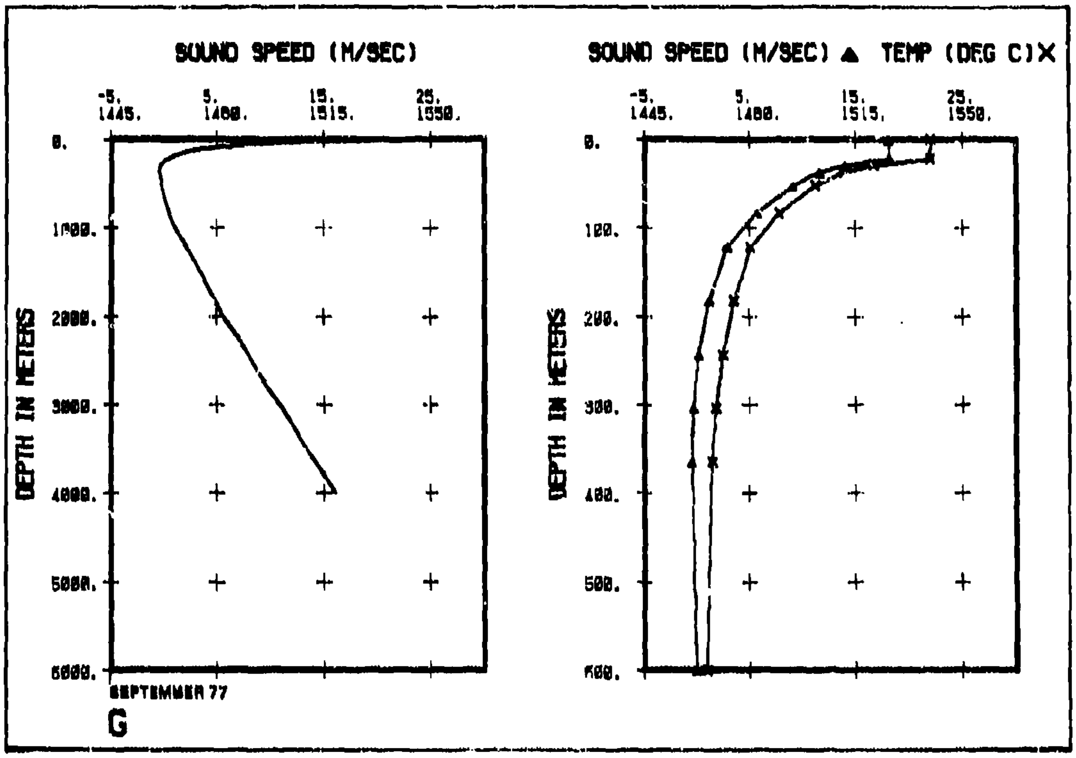


Figure C-22 continued.

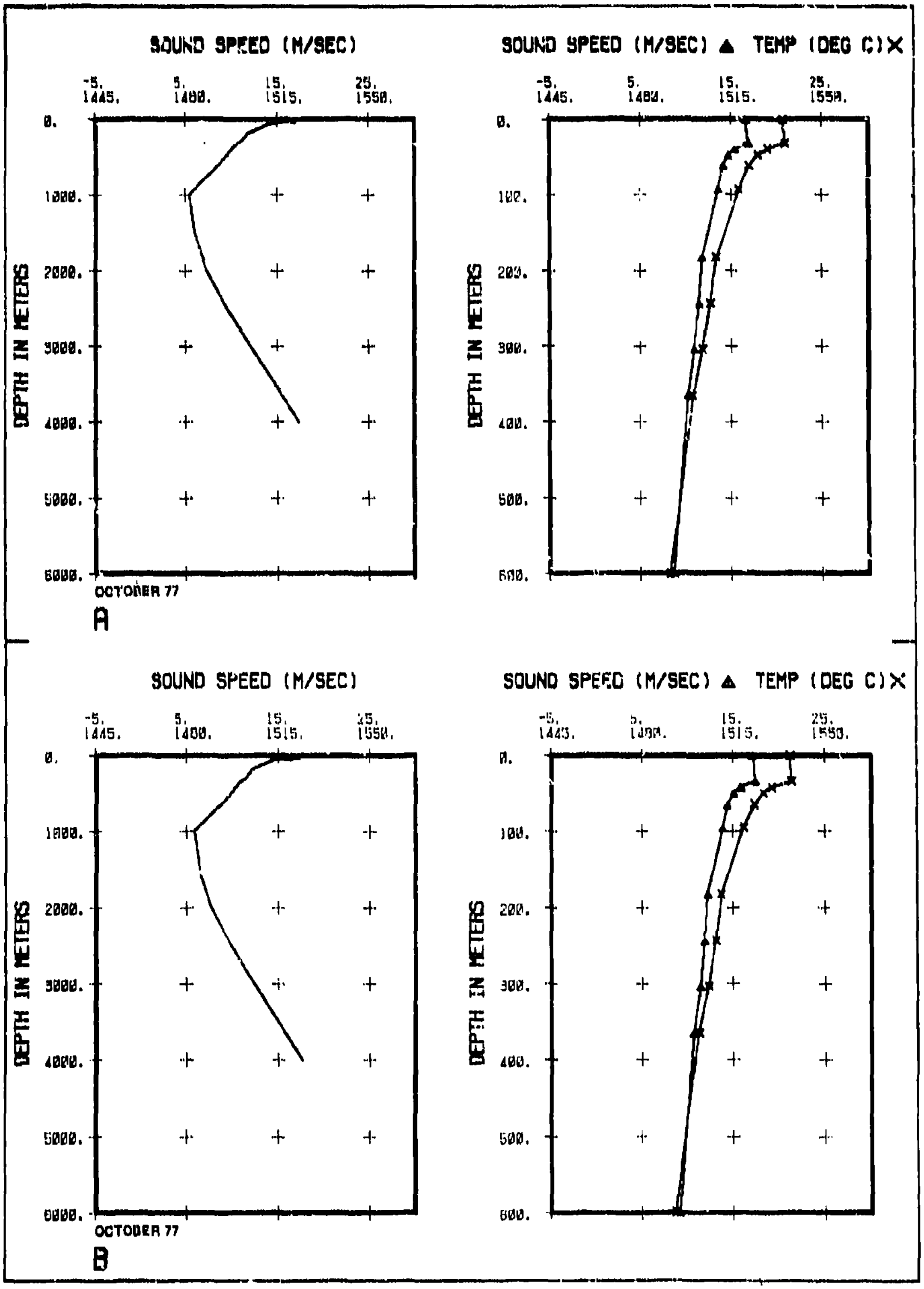
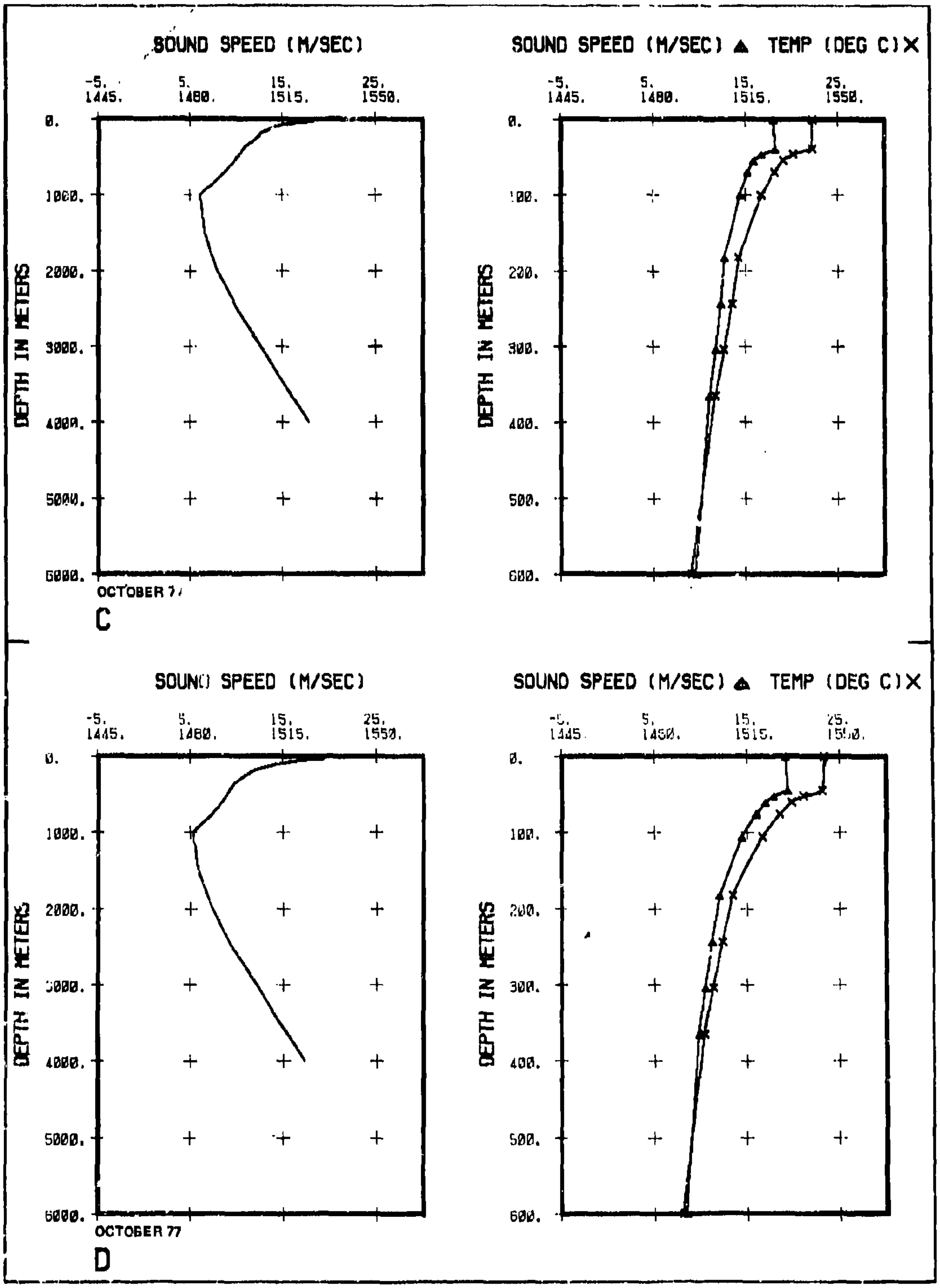


Figure C-23. Profiles for October.



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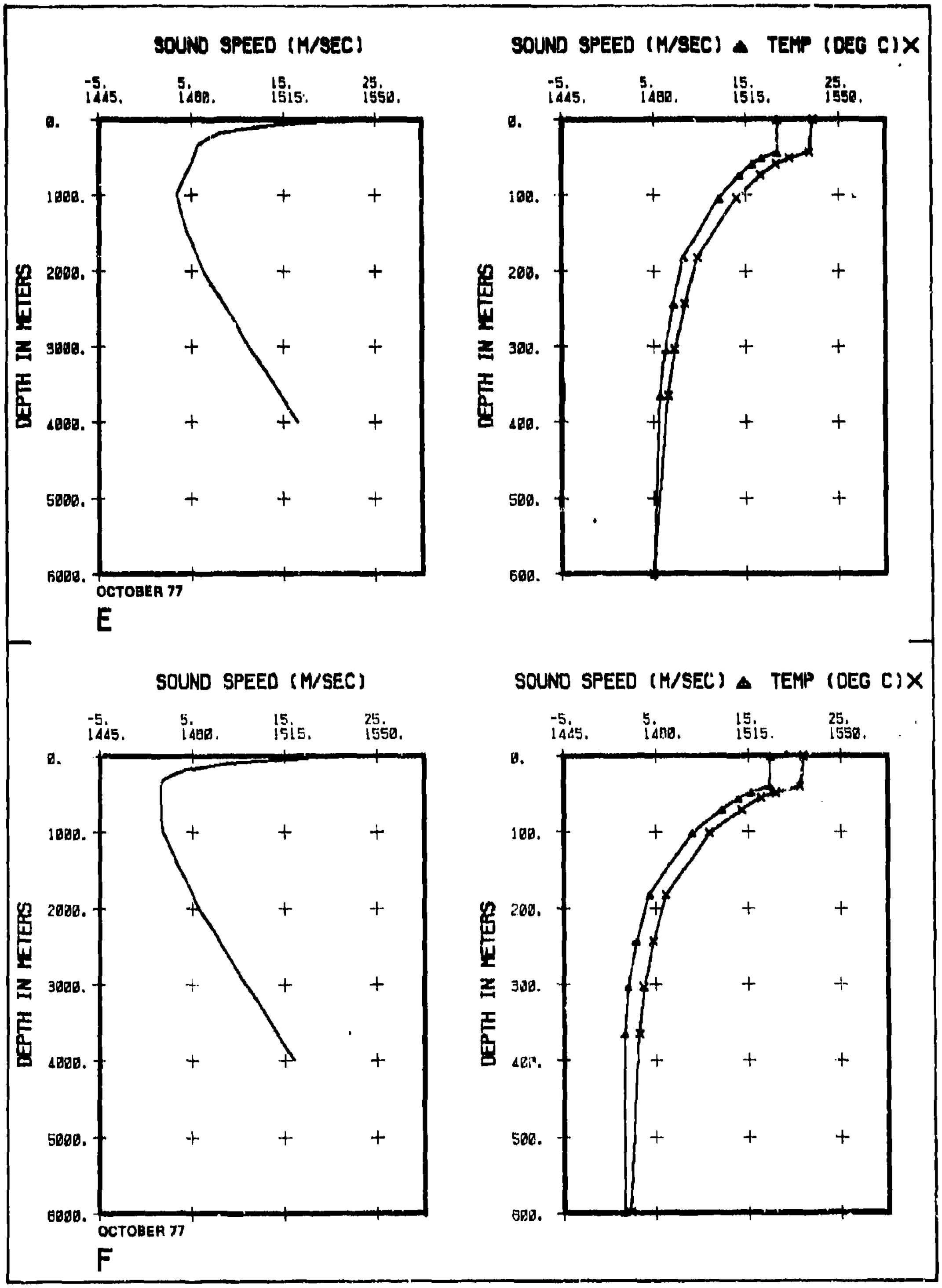

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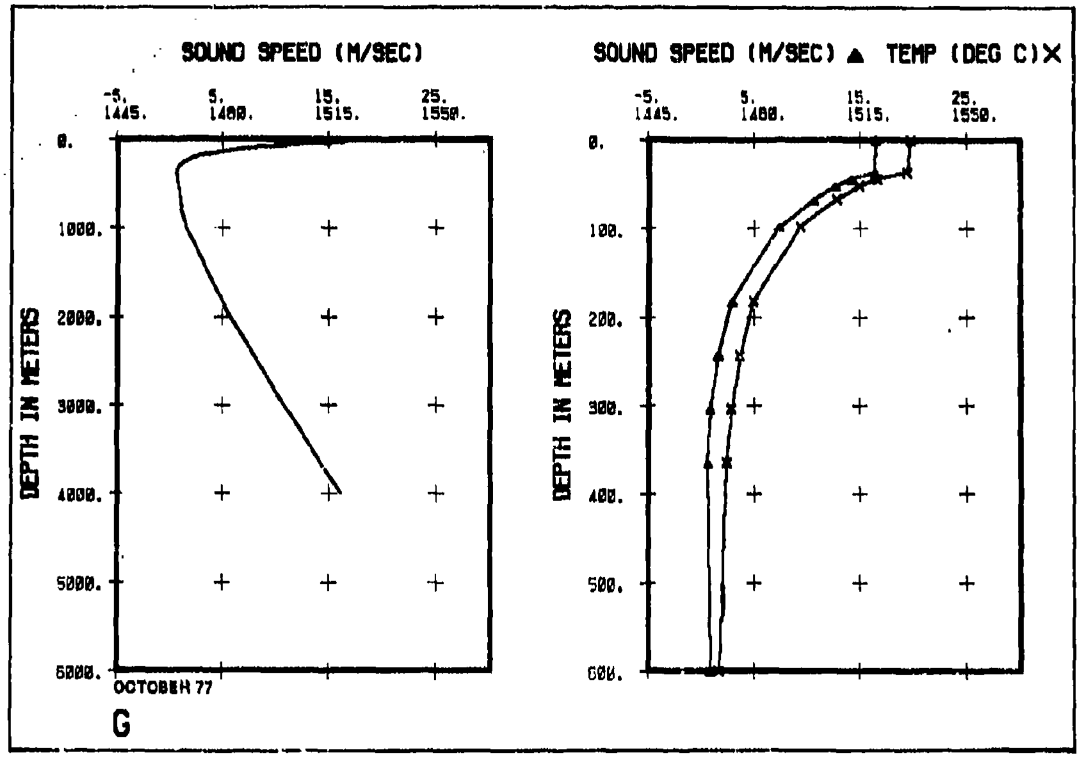

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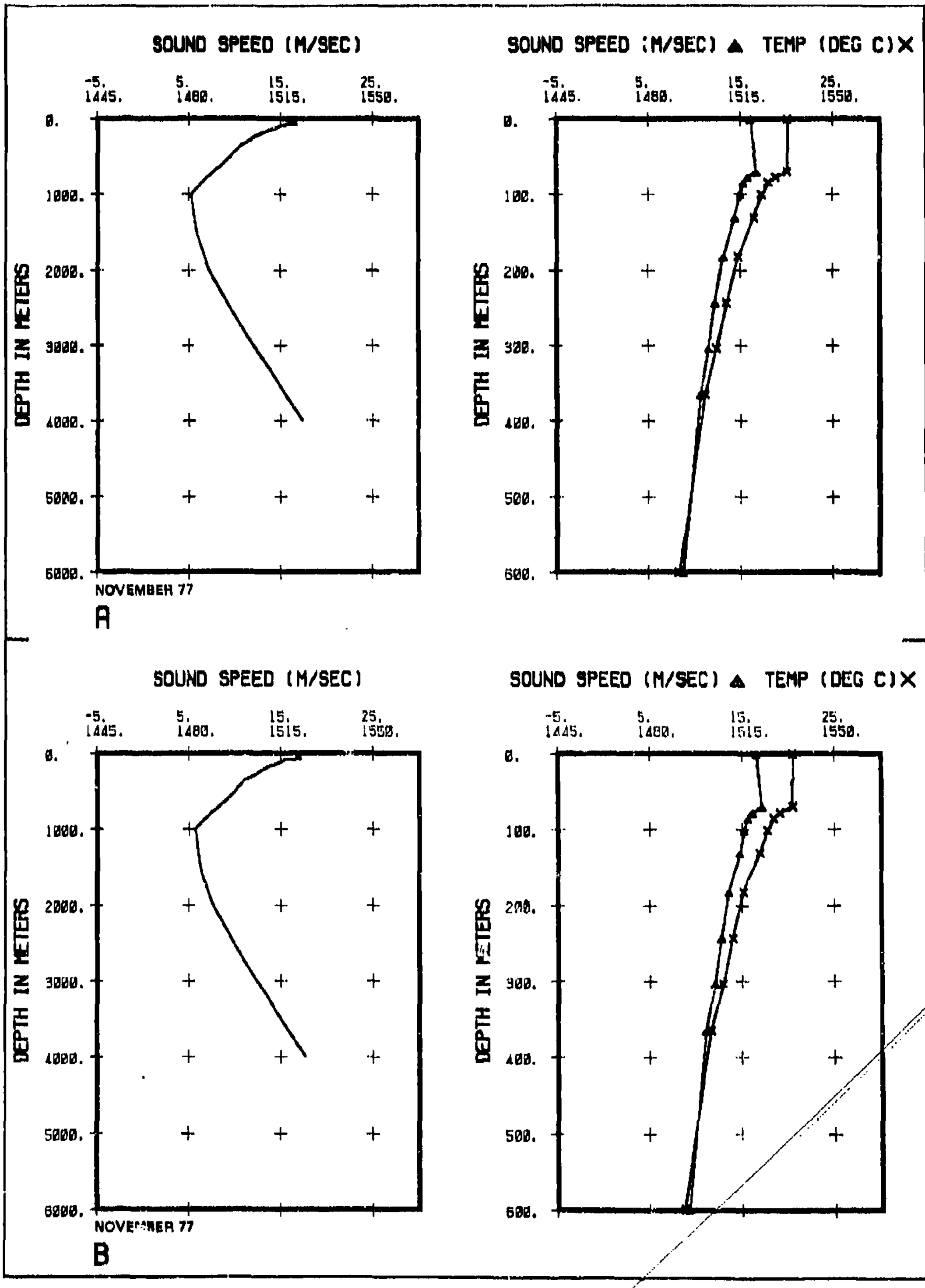
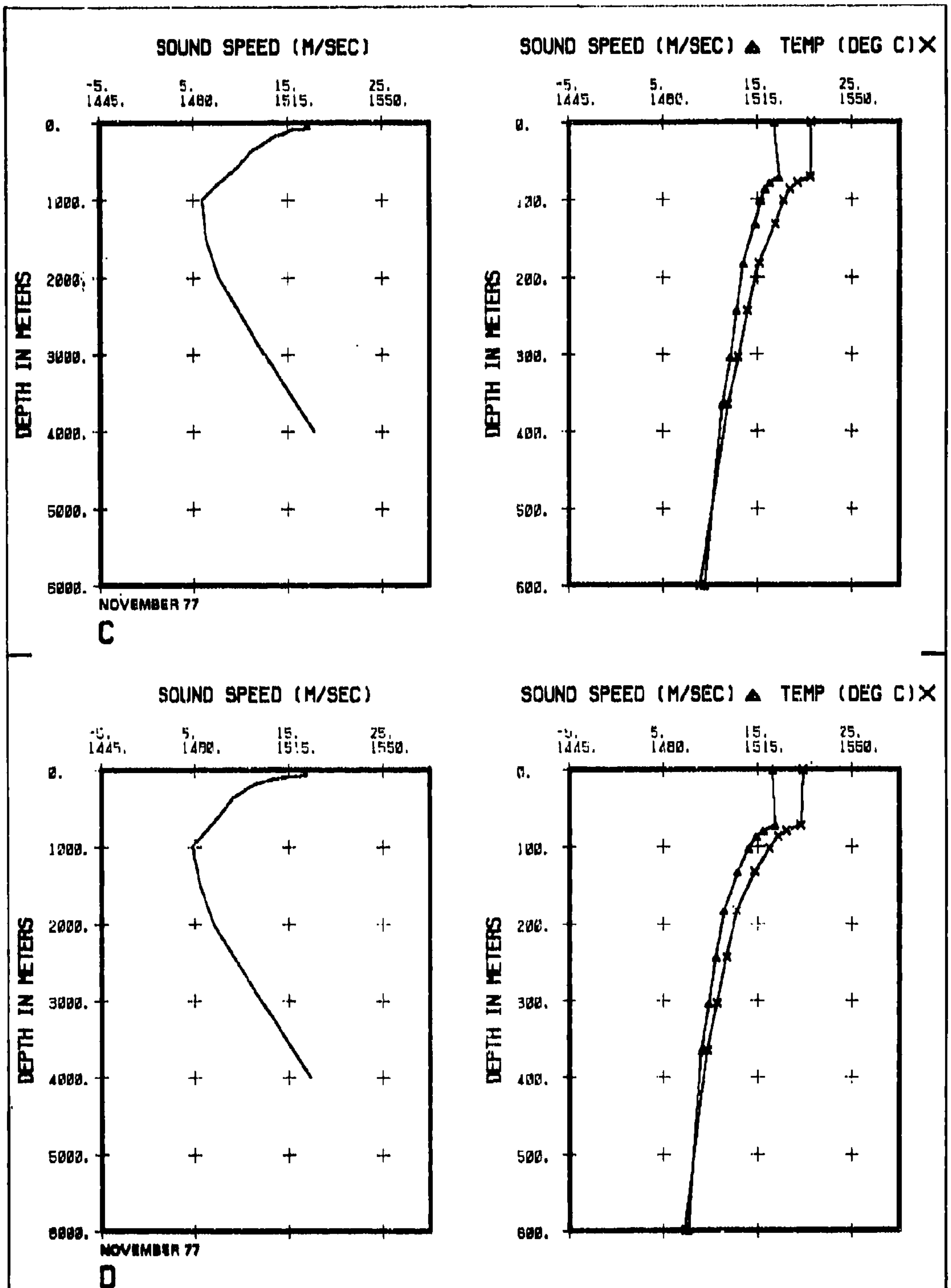


Figure C-24. Profiles for November.



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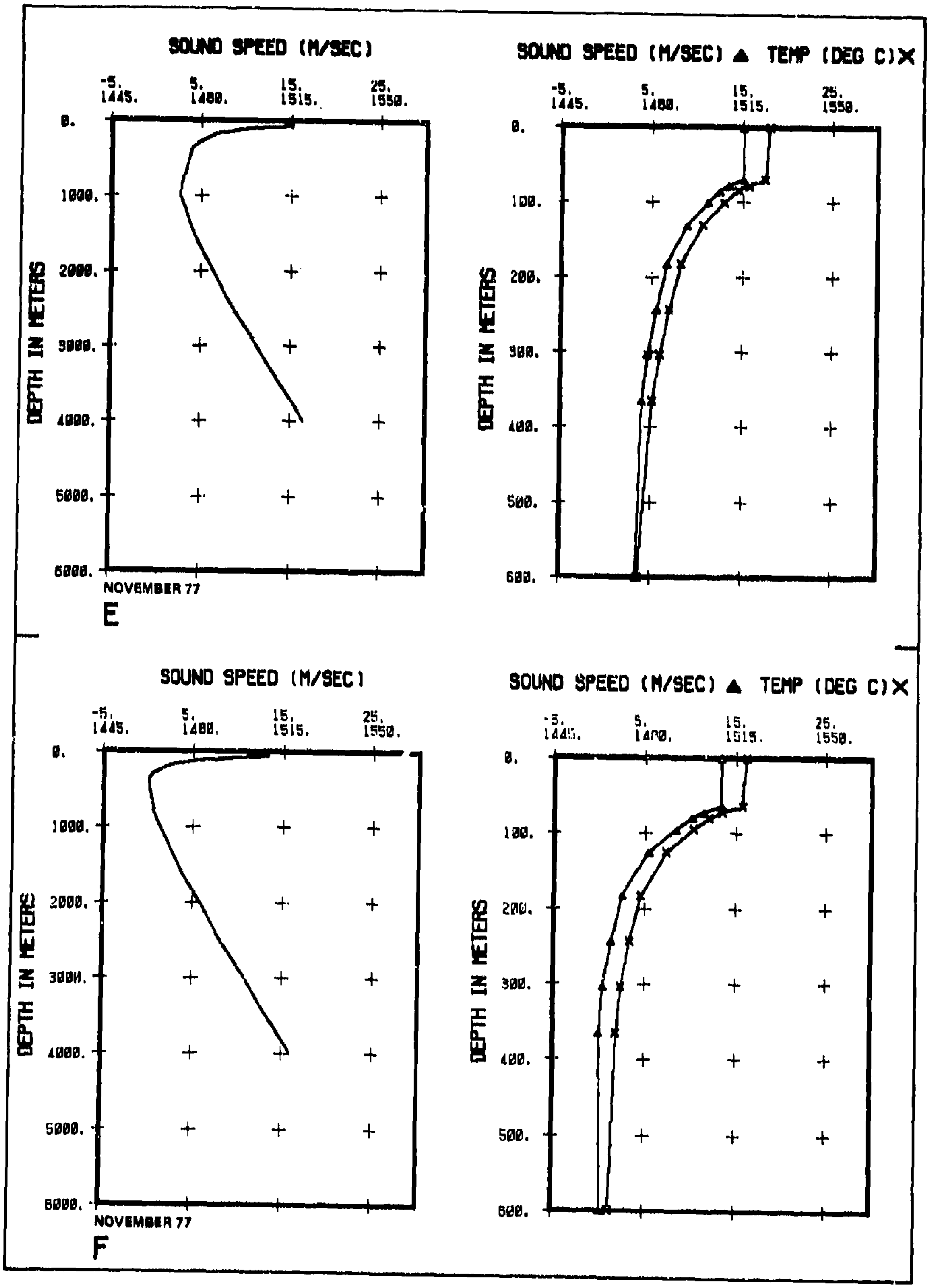

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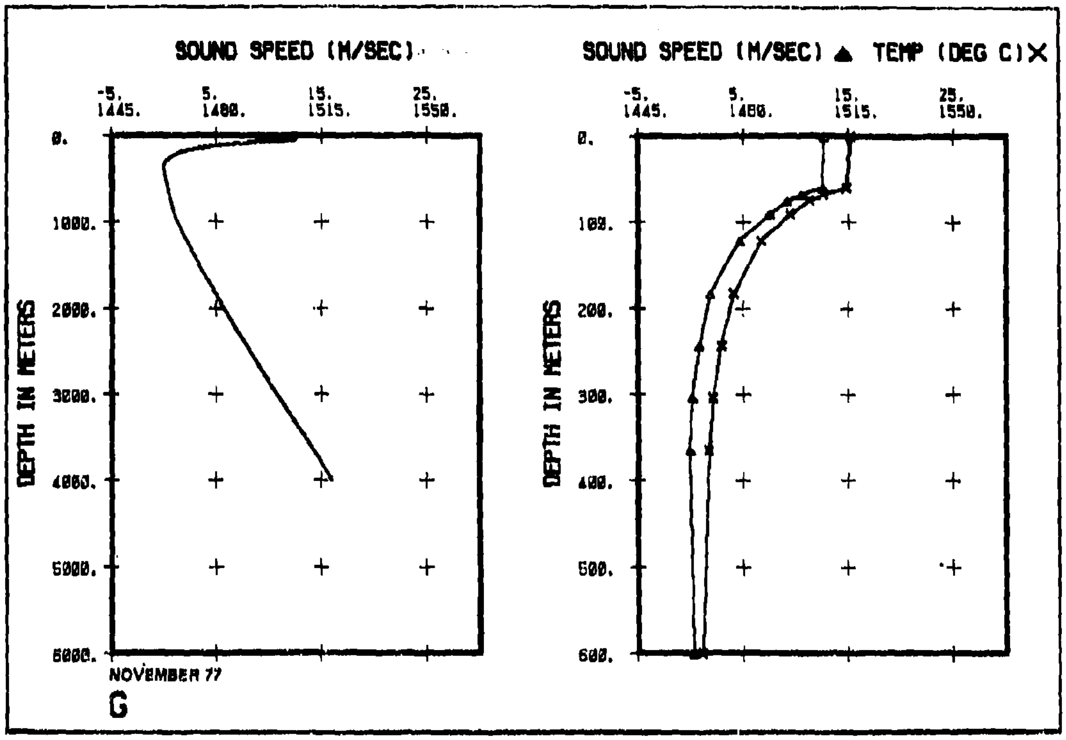

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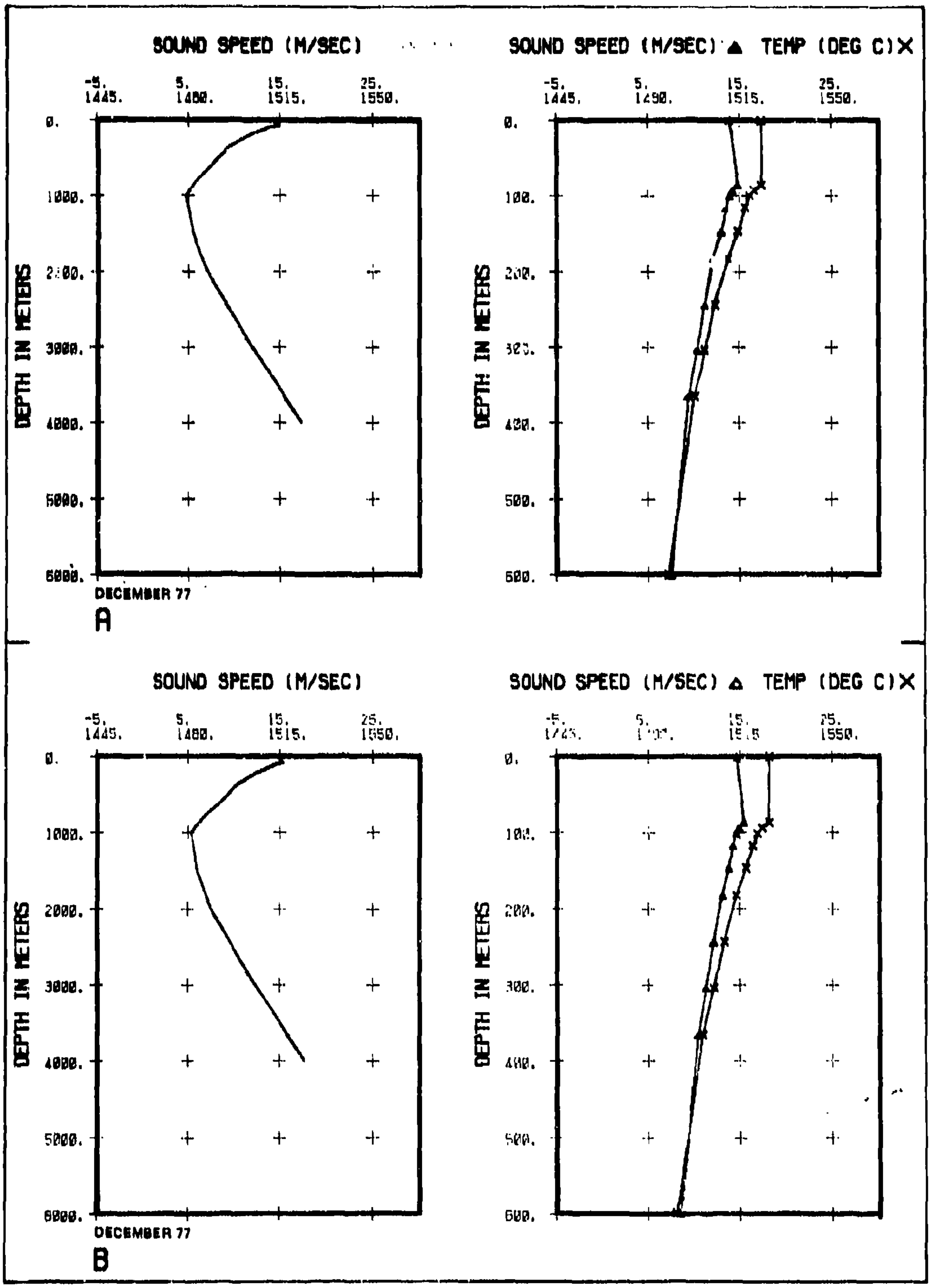


Figure C-25. Profiles for December.

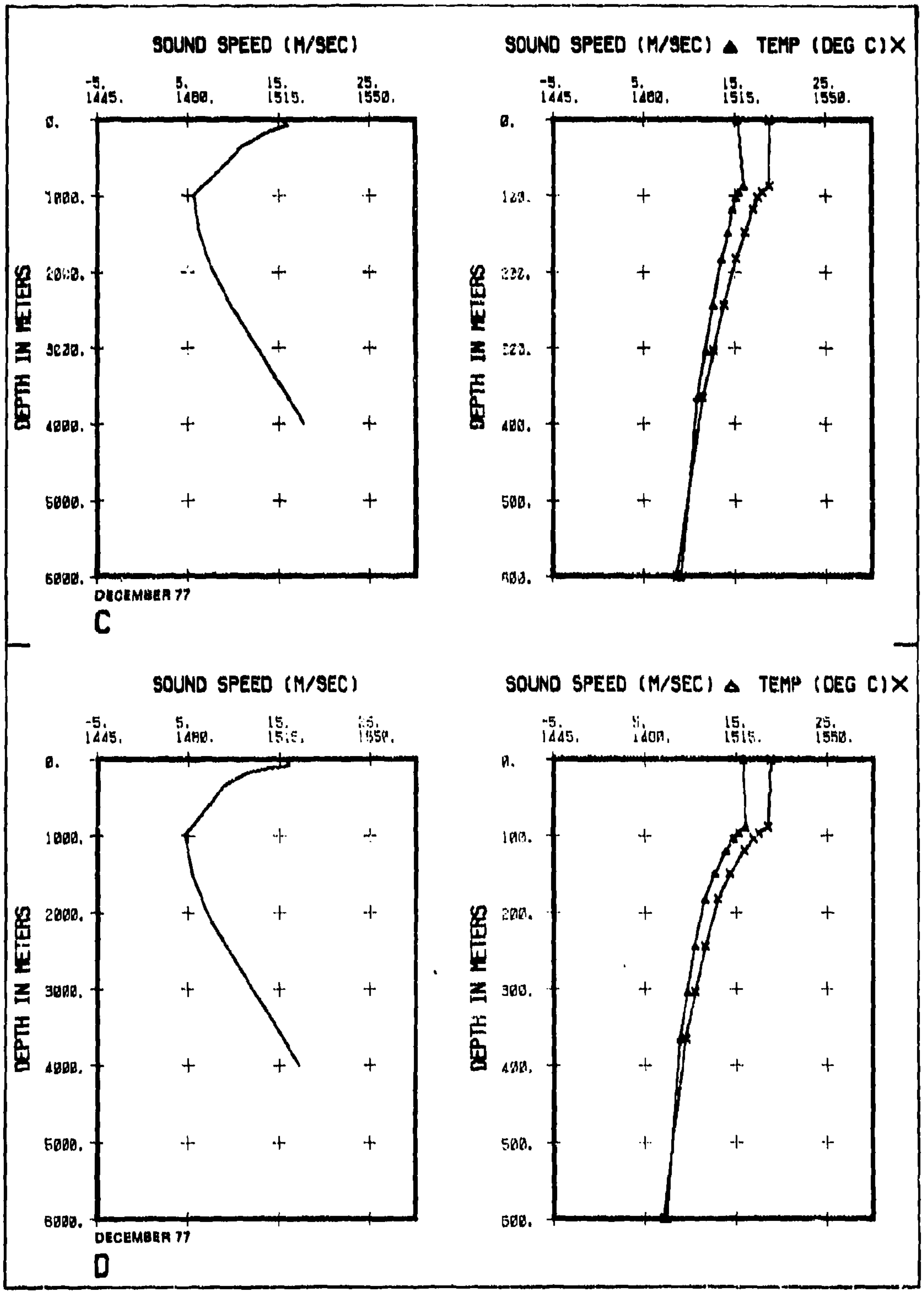
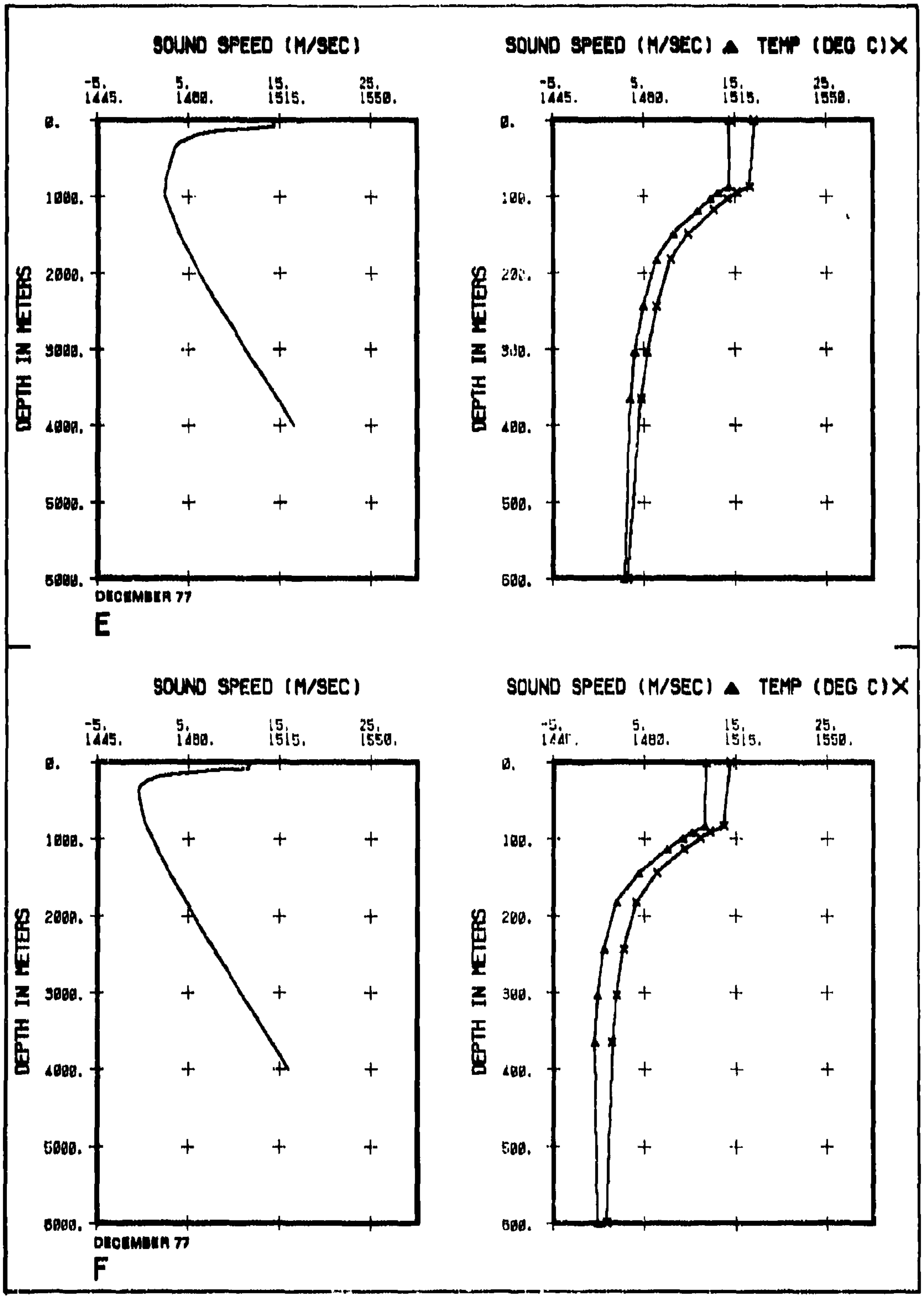


Figure C-25 continued.



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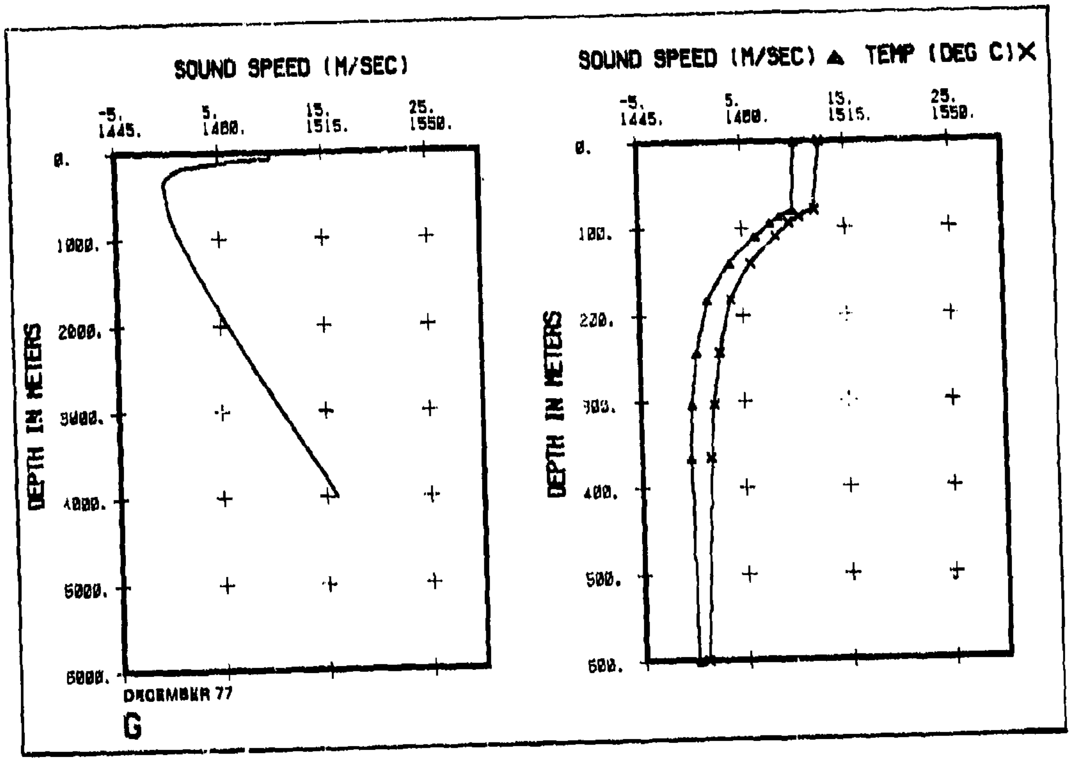

Figure C-25 continued.

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